

TOWARDS A MORE INCLUSIVE SCIENCE :

Open Science and the transformation of knowledge governance

BRIDGE WP4.5 Report

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This report, produced as part of the BRIDGE Project (WP4), offers a comprehensive and critical investigation into the promises, contradictions, and future trajectories of “open science”. It interrogates how “openness” in science, whether in access to publications, research data, infrastructures, or decision-making, can be meaningfully institutionalised without reproducing historical exclusions or succumbing to neoliberal market logics. Drawing from a wide range of case studies, policy frameworks, and theoretical insights, the report articulates a multi-dimensional approach to understanding the current transformations in knowledge production.

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Abstract

This report, *Towards a More Inclusive Science: Open Knowledge, Public Participation, and Institutional Change (Erasmus BRIDGE WP4 Report)*, examines the evolving landscape of open science (OS) as both a policy orientation and a field of contested practices. It situates OS within the historical and geopolitical contexts of international scientific cooperation, successive waves of digital transformation, and the competitive dynamics of the global knowledge economy. The analysis underscores that while OS promises greater accessibility, collaboration, and societal responsiveness, its realisation is shaped by techno-scientific innovations, such as open access publishing, open-source software, and federated infrastructures, and by enduring structural asymmetries in resources, governance, and epistemic authority.

Drawing on comparative evidence from European and international contexts, the report identifies key trends, opportunities, and constraints. It documents persistent inequalities in access to infrastructures, the concentration of control in a few commercial actors, and the variability of governance models, while highlighting successful initiatives such as the European Open Science Cloud (EOSC), OpenAIRE, Zenodo, and national OS strategies. The study also points to growing integration of citizen science, reforms in research assessment, and emerging solutions for reconciling openness with data protection and sovereignty.

The report concludes that OS must be embedded in coherent, well-resourced, and context-sensitive policy frameworks, supported by robust public infrastructures, interdisciplinary integration, and safeguards against commercial or technocratic capture. It offers ten policy directions, grounded in European experience, that are designed to be feasible, measurable, and adaptable, addressing both systemic challenges and the transformative potential of OS.

Executive Summary

Context and purpose

Open Science (OS) has emerged not only as a central reference in contemporary debates on research governance but, in recent years, as a strong policy orientation actively promoted by governments, intergovernmental bodies, and major research institutions. It promises to make knowledge more accessible, collaborative, and responsive to societal needs. Yet, as the analysis developed in this report underlines, this promise remains complex and contested. It is shaped both by techno-scientific transformations that expand the possibilities for openness, such as the digitalisation of research processes, the proliferation of open access publishing, open source software, and collaborative platforms, and by structural constraints and political economies that can both enable and limit systemic transformation.

Towards a More Inclusive Science: Open Knowledge, Public Participation, and Institutional Change (Erasmus BRIDGE WP4 Report) situates OS within the broader historical trajectory of international scientific cooperation, encompassing post-war multilateral frameworks, successive waves of digital transformation in research practices, and the increasingly competitive dynamics of the global knowledge economy, where states, institutions, and private actors contend for technological leadership and epistemic authority. It builds on a double observation. First, the vocabulary of openness is increasingly universalised, endorsed by intergovernmental organisations, national research councils, and institutional leaders. Second, the translation of these principles into practice varies in depth, coherence, and sustainability, depending on governance models, resources, and the balance between public, private, and civic actors.

This analysis rests on a comparative reading of national strategies, regional initiatives, and institutional reforms, combined with an examination of the infrastructures, standards, and evaluation mechanisms that underpin OS. It shows that while the rhetoric of inclusion has gained ground, its practical realisation depends on navigating a polarised, semi-integrated system of knowledge production, in which certain regions, networks, and institutions hold disproportionate infrastructural and epistemic power, but also where innovative, collaborative, and locally adapted models continue to emerge.

Key Findings

- **Evolving structural inequalities** – Disparities in infrastructure, funding, and influence remain, but European initiatives such as EOSC's training and support hubs, and national OS competence centres in Finland and the Netherlands, demonstrate how sustained, targeted investments can close capacity gaps.
- **Concentration and innovation in infrastructures** – While commercial actors dominate bibliometric and dissemination tools, public platforms like OpenAIRE and HAL, as well as Zenodo hosted by CERN, prove the feasibility of robust, scalable alternatives when supported by long-term EU and national funding.

- **Diverse governance models** – Legislative and strategic frameworks in countries such as France and Slovenia have produced measurable improvements in OS adoption; EOSC’s governance demonstrates the added value of multi-country alignment.
- **Expanding citizen science practices** – Projects like WeObserve and Cos4Cloud have successfully linked community data to European policy processes, influencing environmental and urban planning.
- **Reform challenges in evaluation systems** – The uptake of DORA principles and CoARA’s roadmap across European institutions illustrates a pathway for recognising OS outputs beyond journal articles.
- **Navigating data sovereignty** – GDPR-compliant models and initiatives like the European Health Data Space show how openness can be reconciled with stringent data protection.
- **Normative leadership with local adaptation** – EC OS policy frameworks have driven reforms where adapted to local contexts, e.g., ERA Action Plans integrated into national research agendas.
- **Emergence of federated infrastructures** – EOSC’s national nodes highlight that interoperability and multilingual governance are achievable at scale.
- **Interdisciplinary potential** – EU Missions such as Climate-Neutral and Smart Cities demonstrate effective SSH-STEM integration.
- **Balancing innovation and safeguards** – Oversight models in Denmark and the Netherlands maintain transparency and ensure that public-private OS projects serve public value.

Implications

Open Science is not a neutral technical evolution but a dynamic arena where contrasting visions of knowledge production interact. The challenge is to harness its transformative potential while addressing persistent asymmetries. Achieving this requires policies that align infrastructures, governance, and evaluation systems with inclusivity, while leveraging techno-scientific advances and local capacities.

Ten policy directions

- **Institutionalise OS through law and long-term funding** – Establish binding national OS frameworks, with five- to ten-year funding cycles, implementation milestones, and annual progress reviews, inspired on France’s National OS Plan and Slovenia’s OS Strategy.
- **Develop public, federated infrastructures** – Expand platforms like OpenAIRE and Zenodo with secure, interoperable architectures, EU–Member State co-funding agreements, and transparent governance boards including user representation.

- **Reconfigure research assessment** – Mandate the integration of CoARA and DORA principles into national evaluation agencies, piloting these in funding calls and tenure processes before scaling nationally.
- **Embed OS in governance structures** – Include open science key performance indicators (KPIs) in institutional performance contracts, link them to ERA Action Plan deliverables, and require public annual reporting on progress.
- **Link citizen science to policy** – Establish formal protocols for validating and incorporating citizen-generated data into EU reporting frameworks, with dedicated budget lines for data quality assurance.
- **Prevent policy capture** – Require conflict-of-interest declarations for all OS governance bodies, ensure independent chairs, and publish meeting minutes and decisions.
- **Support multilingualism and local knowledge systems** – Fund translation, indexing, and curation services ; integrate indigenous and local knowledge into open science (OS) repositories, leveraging European initiatives such as the European Language Grid and national multilingual archiving projects.
- **Integrate data sovereignty safeguards** – Develop adaptable licensing templates compatible with the General Data Protection Regulation (GDPR) and specific sectoral regulations, such as those governing health or environmental data; conduct national-level audits to ensure compliance and publish public summaries of findings to promote transparency.
- **Connect global norms to local action** – Translate UNESCO and EC OS guidelines into actionable national toolkits, provide training for institutional OS officers, and link uptake to eligibility for EU research funding.
- **Foster interdisciplinary OS ecosystems** – Allocate targeted Horizon Europe funding streams for SSH-STEM collaborations, require interdisciplinary work packages in mission-oriented projects, and track outputs via OS-compliant repositories.

Introduction

Open Science refers to a broad movement that seeks to make scientific research processes and outputs more accessible, transparent, collaborative, and reusable. It encompasses open access to scholarly publications, open research data, open source software, transparent peer review, and deeper engagement between science and society. More than a collection of practices, Open Science represents a profound reconfiguration of knowledge production, a shift that reorganises how research is conducted, shared, and valued across institutional, disciplinary, and technological contexts. Rooted in ideals of accessibility, transparency, collaboration, and reproducibility, Open Science is not only a technical evolution in scholarly communication but also a politically and epistemologically charged transformation.

It must therefore be understood as a historically and politically situated process. Open science is shaped by layered and often conflicting rationalities: state policy priorities, academic incentive systems, corporate interests, and activist demands for epistemic justice. It is a site of negotiation, where infrastructural choices, licensing conditions, and definitions of “openness” are entangled with questions of economic value, scientific authority, and geopolitical asymmetries. These dynamics echo longstanding tensions within science itself, between autonomy and accountability, public good and proprietary control, and dominant epistemologies versus calls for cognitive justice from under-resourced or marginalised research systems.

Open science did not emerge in a vacuum. Its ideals of transparency and collective endeavour have long been part of scientific discourse, yet they have always been intertwined with political and economic interests. From the Enlightenment vision of rational and collective science, through the 19th century consolidation of the modern university, to the mid-20th century alignment of science with state and industrial agendas, research has repeatedly been shaped by broader societal forces. In the late 20th century, the rise of market logics and digital technologies restructured academic labour, created new performance pressures, and introduced dependencies on private platforms. Open Science has taken form precisely within this moment of crisis and transformation, not as a spontaneous emancipation, but as a contested response to the contradictions of contemporary knowledge regimes.

This report is structured around a series of guiding questions and hypotheses, each explored through one of the eleven chapters:

1. How did the development of modern science lay the groundwork for current Open Science debates, and what institutional legacies persist?
2. Can Open Science reconcile the universalist claims of scientific objectivity with calls for epistemic justice and contextual knowledge?
3. In what ways has the Open Science movement evolved, and do its promises of democratisation hold against persistent structural inequalities?
4. What pressures, from ecological crises to digital infrastructures, constrain or accelerate the transformation of knowledge systems?

5. How are communication practices and academic visibility being redefined in the context of publishing monopolies and metric-driven evaluations?
6. To what extent have institutions, states, and international bodies embraced Open Science, and what models of governance prevail?
7. How does Open Science intersect with public–private dynamics, and what risks arise around intellectual property and innovation policy?
8. What role do geopolitical configurations play in shaping global norms and asymmetries in Open Science implementation?
9. How can citizen science and public participation be meaningfully integrated into knowledge production without remaining symbolic or superficial?
10. What changes in career structures, recognition systems, and capacity building are necessary to empower researchers and stakeholders?
11. Which concrete policy recommendations could foster inclusive, sustainable, and democratically governed Open Science ecosystems?

Our analysis draws on a broad interdisciplinary framework, integrating insights from critical social science, political economy, science and technology studies, as well as cognitive science, anthropology and sociology of science, management studies, and comparative higher education research. This grounding underscores that Open Science must not be seen as a neutral or technocratic endpoint, but rather as a contested and evolving terrain. Research in the cognitive sciences shows how reasoning in science is shaped by bounded rationality and cognitive constraints. Anthropological and sociological perspectives demonstrate how epistemic cultures, material settings, and social negotiations shape what counts as legitimate knowledge. Management and organisational studies highlight the effects of incentive structures, performance indicators, and governance frameworks on research quality and direction. Comparative higher education research shows how Open Science trajectories differ widely across contexts, depending on governance models, policy logics, and academic traditions. Together, these perspectives underline that Open Science is not a linear or universally applicable reform, but a dynamic field shaped by institutional configurations, normative contestations, and sociopolitical asymmetries.

This report thus serves a dual purpose: first, as a meta-analysis of the transformations reshaping the global research ecosystem; second, as an analytical foundation for the next phase of the BRIDGE Project, identifying how Open Science can support quality, equity, and impact in knowledge production and governance. By critically examining emerging models of knowledge creation, dissemination, and institutional coordination, we aim to inform policies that foster resilient, inclusive, and democratically governed research infrastructures.

1. Historical context: the ascent of modern science from Enlightenment to Artificial Intelligence

1.1 European roots

The foundations of Open Science can be traced back to the epistemological and institutional shifts of the European Enlightenment. This period saw the emergence of science as a rational, empirical, and public endeavour, gradually diverging from earlier knowledge regimes embedded in esoteric traditions, courtly patronage systems, and ecclesiastical authority. Recent historical scholarship nuances this narrative, showing that continuity and hybridisation were as important as rupture. Early modern scientific practices frequently drew upon artisanal knowledge, religious frameworks, and classical texts, complicating the binary between "modern" and "premodern" science. Instead, scientific rationality evolved through hybrid epistemologies where experimentation coexisted with metaphysical speculation, and where artisanal practices deeply informed elite scientific cultures (Daston & Park, 2001; Raj, 2007; Van Damme, 2018). Historians of sciences underscore the need to attend to the cultural, religious, and political conditions under which modern science was institutionalised in different European contexts. The Royal Society of London and the Académie des Sciences in France exemplified these changes, creating spaces for collective inquiry and systematic publication while also reinforcing hierarchies and social exclusions. Far from a pure ideal of openness, these academies operated within elite networks and served political functions, balancing public visibility with patronage and national prestige (Daston, 1992; Shapin & Schaffer, 1985). This dual role of enabling public knowledge while controlling legitimacy foreshadows tensions that characterise Open Science today.

The ideals that later informed Open Science, accessibility, communal verification, and epistemic accountability, have antecedents in this Enlightenment legacy. Robert K. Merton's canonical articulation of the "normative structure of science" (1942) reinterprets these values for the modern institutional age (communalism, universalism, disinterestedness, organised scepticism), coined as "The Republic of Science" in a seminal article, twenty years after (Polanyi, 1962). Yet these principles were never universally applied: communalism relied on elite correspondence networks and journals that excluded marginal voices; universalism echoed claims of rational objectivity but remained blind to gender, class, and colonial exclusions (Shapin, 1994).

European scientific cultures evolved along divergent national paths. In Britain, Francis Bacon's experimental philosophy championed empiricism and utilitarian knowledge for societal progress, as set forth in *Novum Organum* (1620), but imperial era practices often coupled openness with strategic control for industrial and colonial interests (Secord, 2004). In France, Cartesian clarity and encyclopedic systematisation (Diderot and d'Alembert) formalised knowledge for civic instruction while reinforcing socio-cultural exclusions. In Germany, Kantian reason and Humboldtian reforms favored autonomous scholarship within universities, privileging the unity of research and teaching over broader access. Thus, while Enlightenment Europe laid the groundwork for modern science, it also institutionalised selective openness. The infrastructures that emerged, academies, journals, encyclopedias, were enabling yet exclusive. This legacy remains visible in today's debates on Open

Science (who participates, who benefits, whose knowledge is recognised), reminding us that "openness" has never had a single meaning and is conditioned by institutional context.

1.2 Institutionalisation and the professionalisation of science

The 19th century marked a critical moment in the consolidation and professionalisation of science, laying foundations for structures and hierarchies that still govern knowledge production. Across Europe and North America, inquiry transitioned from amateur pursuits to regulated, state-supported professions, embedded in industrialisation, nation-building, and colonial expansion that linked science to state power and economic growth (Elshakry, 2010; Pestre, 2003). Among emerging forms, the Prussian research university, often associated with Wilhelm von Humboldt's early 19th century reforms of Berlin University and its later success, proved especially influential. Rooted in *Bildung* (personal and civic formation) and *Wissenschaft* (holistic pursuit of knowledge), it emphasised the unity of research and teaching (*Forschung und Lehre*) and scholarly autonomy. While Humboldt's ideal resisted instrumentalisation and upheld knowledge as an end in itself (Ruano-Borbalan, 2022; Kirby, 2022), implementation varied and was shaped by political pressures, budgets, and social stratification.

In France, the university system developed in parallel with the *Grandes Écoles* designed to train administrative and technical elites, reinforcing the division between academic research and applied science. In England, the dominance of Oxford and Cambridge led to regional development disparities. In the United States, land grant institutions created by the Morrill Act (1862) expanded access but did not resolve stratification between elite private universities and publicly funded colleges (Geiger, 2004). Professional societies, doctoral programs, and peer-reviewed journals (such as *Nature* in 1869 and the *Comptes Rendus* in France, established in 1835 by the French Academy of Sciences) formalised careers and dissemination while entrenching prestige, authority, and exclusion (Chadarevian & Kamminga, 1998). The spatial geography of knowledge production grew increasingly skewed as European and North American centres exported their models via imperial networks, marginalising local and Indigenous epistemologies (Raj, 2007). Thus emerged a double movement: codification of norms and greater autonomy from aristocratic or religious oversight, alongside mechanisms of stratification that still influence validation, publication, and circulation globally.

1.3 Post-War expansion of science and the "Endless Frontier" knowledge regime

The post-World War II era saw unprecedented expansion in state led research, embedded in Cold War geopolitics and a consensus on science as a strategic national asset. The famous Vannevar Bush's report (*Science, The Endless Frontier*, 1945) articulated a vision in which federally funded research would fuel growth, technological superiority, and national security, underpinning institutions like the U.S. National Science Foundation and a model that tightly linked knowledge production to military and economic imperatives. In the United States, state–industry–academia alignment generated a military-industrial-academic complex; Sputnik (1957) triggered massive funding for science and technology. In the Soviet Union, in the same period, science was organised through centralised institutions (e.g., Academy of Sciences of the USSR), focused on space,

nuclear energy, and cybernetics, with ideological conformity, mass STEM education, and rapid technological advancement, yet constrained by bureaucracy and limited international collaboration (Gerovitch, 2020; Kremontsov, 2022). In postwar Japan, the Ministry of Education, Science and Culture, alongside industrial actors like MITI, promoted coordinated science-technology policy for reconstruction and catch-up, spurring globally competitive electronics and materials science (Kodama & Shibata, 2020; OECD, 2021). Much like Germany, Japan pivoted toward civilian techno-scientific innovation, emphasising precision engineering, quality control, and government-guided R&D (Kodama & Shibata, 2020; OECD, 2021). This aligned with a "developmental state" model integrating industrial policy and research investment. Unlike the U.S. military-industrial-academic model, Japan relied on private-industry integration, export led growth, and *kaizen*, reinforced by Science and Technology Basic Plans, positioning Japan as a leader by the 1980s (Kondo, 2020; Murakami, 2016;). By the 1980s, however, U.S. trade pressure and redirected investment in computing and biotech, and later competition from South Korea and China, reshaped trajectories (Freeman, 1987; Lee, 2013; Odagiri & Goto, 1996). These shifts illustrate how geopolitical hierarchies and reactive policy ecosystems shaped national science systems. Strategic disciplines such as physics, aerospace engineering, and computing received concentrated support, reinforcing hierarchies within the scientific community (Guston, 2022).

Across Europe, similar processes unfolded in diverse configurations. The foundation of CERN in 1954, supported by multiple states, represented a landmark in international collaboration and high-energy physics, embodying Western Europe's ambition to reclaim technological prestige and foster regional integration while exemplifying centralised, disciplinary infrastructures (Krige, 2022). Such institutionalisations, however, reinforced hierarchical regimes privileging large-scale experimental sciences aligned with state strategic interests, marginalising social sciences and humanities (Felt, 2020; Weingart, 2005). They also entrenched spatial and institutional asymmetries by consolidating resources within elite or metropolitan institutions, underfunding smaller or peripheral centres, especially in Southern and Eastern Europe (Benner et al., 2020). Despite policy rhetoric (Horizon 2020, Horizon Europe), transdisciplinary collaboration was often disincentivised by fragmented instruments, disciplinary excellence indicators, and weak incentives. The ERC has been criticised for awarding disproportionately to disciplinary projects based in elite institutions (Lepori et al., 2020). FP7 and H2020 revealed persistent imbalances, Western/Northern institutions captured most grants while Eastern/Southern actors struggled, even in collaborative projects (Schoen et al., 2021; Lungu & Ivan, 2020). In Horizon 2020, the top five EU countries (France, Germany, Netherlands, Spain, UK) coordinated over 60% of projects, while Romania, Bulgaria, and Croatia remained underrepresented (European Commission, 2020). ERC grants have consistently favored Western institutions and elite universities, with <3% going to the bottom 15 EU countries by research performance (Lepori et al., 2020).

These imbalances raise concerns about cumulative advantage that further marginalises less resourced institutions and regions. Colonial and postcolonial dynamics continued to diffuse Euro-American scientific norms, privileging knowledge aligned with developmentalist or security-oriented priorities (Harding, 2011). Meanwhile, civic participation narrowed: CSOs and grassroots actors reported diminished access to funding and

influence, the “shrinking civic space” (Buyse, 2018; CIVICUS, 2023), as expert-driven, performance-oriented infrastructures prioritised competitiveness and innovation outputs over public deliberation and inclusion (Felt, 2017; Pellizzoni, 2020; Stirling, 2019; 2017).

1.4 The digital turn and the contradictions of openness in knowledge production

The late 20th/early 21st century digital revolution profoundly restructured scientific knowledge production, introducing tools, platforms, and networks that facilitate openness, collaboration, and accelerated discovery. Frequently heralded by UNESCO, the European Commission, and major Open Science declarations as democratising, this transition has enabled faster dissemination, broader data access, and collaborative infrastructures. Initiatives such as Plan S (launched in 2018 by cOAlition S funders to require immediate open access to publicly funded research from 2021 onward), the European Open Science Cloud (EOSC, formally launched by the European Commission in 2018 as a federated environment for sharing and reusing research data across borders and disciplines), and global preprint repositories have significantly contributed to knowledge equity and innovation.

However, the digital transition is not without contradictions. Compliance ready infrastructures and funding remain concentrated in well-resourced institutions in Western Europe and North America. In artificial intelligence (AI), covering machine learning, deep learning, and natural language processing, the disparities are stark, as access to large datasets, advanced computing power, and specialised expertise is concentrated in a handful of elite centres. China, however, represents a particular case: through massive public investments, the mobilisation of its technology giants (Baidu, Alibaba, Tencent, Huawei), and national programmes such as the 2017 initiative aiming to make the country a global leader in AI by 2030, it has rapidly built infrastructures and a research ecosystem that now rival North America and Europe, while maintaining strong state centralisation in science governance.

The GPT series (OpenAI) and WuDao (BAAI) exemplify a race between well-funded actors in the U.S. and China, consolidating innovation in a few geopolitical centres (Liang et al., 2022; UNESCO, 2023). These developments expose an asymmetrical geography of digital capacity and challenge narratives of universal openness (Bridle, 2022). While AI offers opportunities across domains, proprietary algorithms, privileged access to compute, and linguistic biases can skew epistemic outcomes and exacerbate inequalities (Bender et al., 2021; Crawford, 2021). Countervailing efforts, such as Europe’s AI Act and open source consortia, seek to promote transparency, ethical accountability, and more distributed capacity.

Concrete imbalances persist. Large language models such as GPT-4, Gemini, and LLaMA-3 require vast compute infrastructures, predominantly concentrated within hyperscale U.S. cloud platforms. As of 2025, the Trump administration has expanded public investment into AI and semiconductor research through CHIPS Act II, emphasising AI defence integration and domestic production autonomy. In the European Union, Digital Europe and Horizon Europe have been reinforced by national plans, Germany’s AI Action Plan 2025, France’s Strategy for Digital Sovereignty, and Finland’s AI Lighthouse initiatives, to boost open innovation and reduce dependence

on U.S./Chinese infrastructures; despite this, EU public research often relies on transatlantic or private platforms for high-performance computing access. China has intensified strategy via WuDao 3.0 and a new phase of the New Generation AI Development Plan (2025–2030); Japan has consolidated a public–private “Moonshot AI” program for edge AI and ethical robotics. BRICS countries have adopted differentiated strategies: Brazil’s Open AI infrastructure roadmap (public university collaboration); India’s expanded National AI Mission (health, agriculture); South Africa’s investment in sovereign data infrastructures. These dynamics underscore that the global AI race represents a reconfiguration of scientific capacity shaped by political agendas, infrastructural asymmetries, and economic strategies (Ananny & Crawford, 2024; OECD, 2025; Ornston, 2023). What is at stake is the ability of states and blocs to inscribe strategic priorities into future knowledge architectures. As computational infrastructures and AI platforms become critical resources, access, control, and sovereignty determine who participates in frontier research, reproducing older patterns of exclusion and hierarchy.

Despite the promise of expanded access through open access journals, preprints, and data-sharing initiatives (e.g., the Human Genome Project; FAIR principles), benefits remain unequal. Commercial publishing groups (Elsevier, Springer Nature), APC-based models, and metric-driven governance introduce new exclusions, particularly for under-resourced researchers and institutions. Reform initiatives, such as CoARA or national policy shifts in France and the Netherlands, seek to counterbalance these trends. However, as detailed in Chapters 5 and 6, transformations remain constrained and require coordinated efforts to build sustainable, equitable, and inclusive publishing ecosystems.

Understanding the digital transition requires a long-term historical perspective aligned with trajectories of modern science. Enlightenment academies reflected prevailing social hierarchies, and postwar science complexes institutionalised state-driven agendas. In a comparable way, today’s digital infrastructures reinforce economic stratification, platform dependence, and global competition. Technological change alone does not produce epistemic democratisation, as shown in analyses of science and technology policy that emphasise the mediating role of institutions and power structures (Mirowski, 2018). In this perspective, technology acts less as an autonomous driver of openness than as an enabler whose effects depend on governance, incentives, and collective choices about how infrastructures and knowledge systems are organised. Yet open science policies, particularly within the European Research Area (ERA), can rebalance some asymmetries. Initiatives such as EOSC, reform of research assessment (CoARA), and FAIR data governance are tangible steps toward a more inclusive ecosystem. Horizon Europe embeds open science principles as cross-cutting obligations to enhance trust, reproducibility, and interdisciplinarity. These efforts demonstrate a strategic commitment to making openness a policy goal supported by infrastructure, funding, and governance reform (European Commission, 2022; Fecher et al., 2023).

Therefore, open science must be examined as a dynamic, evolving field shaped by overlapping structures of agency, governance, and epistemic justice, its promise lying in the balance between critical scrutiny and constructive policy engagement. By acknowledging its tensions and building on existing policy commitments, particularly within the European Research Area, stakeholders can help shape open science as a framework that

not only expands access, but also redefines participation, ownership, and responsibility in knowledge production.

2. The epistemological foundations: knowledge as social construction

2.1 The nature of knowledge production

Building upon the historical and institutional insights of Chapter 1, which traced the emergence of modern science through its entanglement with political power, state-building, and techno-industrial infrastructures, this section turns to a crucial complementary dimension: the epistemological transformation that reshaped how science itself is conceptualised from the mid-20th century onward. As new fields emerged, from molecular biology and computing to artificial intelligence and climate modeling, the very status of scientific knowledge, as objective, cumulative, and universal, was increasingly questioned. This shift did not mark the end of science's authority, but rather provoked a rethinking of its foundations, actors, and legitimacy. By exploring key contributions from philosophy, anthropology, psychology, and sociology, this chapter shows how open science, far from being a purely technical or policy-driven reform, reflects a deeper reconfiguration of what counts as valid knowledge, who can produce it, and how its credibility is socially negotiated.

The epistemological turn in the social sciences profoundly reoriented our understanding of knowledge, not as a neutral reflection of an objective reality, but as a historically contingent, socially situated, and institutionally mediated construct. This shift gained wide recognition with Thomas Kuhn's seminal work, *The Structure of Scientific Revolutions* (1962), which challenged the Enlightenment-rooted ideal of linear, cumulative scientific progress. Kuhn introduced the now-famous concept of "paradigm shifts," whereby periods of normal science are disrupted by revolutionary ruptures that redefine the conceptual frameworks and methodological rules of entire disciplines.

This perspective paved the way for a richer and more nuanced analysis of knowledge production, where the authority of science is no longer grounded solely in empirical verification or logical coherence, but also in the broader historical, institutional, and sociotechnical dynamics in which research takes place. Since the 1970s, detailed empirical studies of scientific practice, across fields such as molecular biology, nuclear physics, cognitive neuroscience, synthetic biology, and climate modelling, have demonstrated that changes in theoretical frameworks are often closely tied to developments in instrumentation, shifts in funding mechanisms, evolving research cultures, and broader geopolitical and economic transformations.

For instance, the rise of genomics as a central discipline in the life sciences was facilitated by the advent of high-throughput sequencing technologies and massive public investments such as the Human Genome Project, while developments in climate science have been shaped as much by satellite imaging, supercomputing, and international IPCC frameworks as by the refinement of climate models themselves. Likewise, the field of artificial intelligence (AI), defined as the design of systems capable of performing tasks that typically require human intelligence, such as perception, reasoning, learning, and language understanding, has evolved through complex interactions between algorithmic breakthroughs, access to training data, compute infrastructure, and geopolitical ambitions in the US, China, and the EU.

Alongside these transformations, the growth of psychology and cognitive science has influenced how scientific knowledge is conceptualised. Cognitive psychologists such as Steven Pinker (2002) and Daniel Kahneman (2011) have examined the evolutionary and cognitive architecture underpinning human reasoning, judgment, and bias, highlighting both the strengths and limitations of scientific objectivity as a purely rational enterprise. Their insights have been instrumental in identifying systematic cognitive heuristics and biases, such as those documented in Kahneman's work on dual-system thinking, which help explain both the power and vulnerability of scientific reasoning.

At the same time, developments in computational neuroscience and artificial intelligence (AI), understood here as the design of systems capable of performing tasks typically requiring human intelligence, such as perception, reasoning, and learning, have further complicated traditional understandings of cognition. Scholars such as Yann LeCun (2022), Edward A. Lee (2020), and Daniel Andler (2021) have investigated the analogies and divergences between human cognitive processing and algorithmic learning models. These parallels have fueled debates about the nature of understanding, the role of data in shaping intelligence, and the epistemological boundaries between natural and artificial agents.

Crucially, these cognitive and AI-driven approaches have begun to influence open science practices in tangible ways. For example, the increasing use of AI for literature synthesis, peer-review assistance, and data pattern recognition raises fundamental questions about epistemic reliability, transparency, and bias in knowledge production. The deployment of AI tools within open science infrastructures demand not only technical refinement but also critical reflection on how such tools mediate evidence evaluation, frame research priorities, and potentially amplify existing epistemic inequalities. These developments underscore a more dynamic epistemology, one where scientific knowledge emerges from complex, hybrid interactions among human cognition, algorithmic mediation, and institutional practice. These developments support an expanded epistemology where knowledge emerges through embodied, distributed, and adaptive systems, across both organic and artificial intelligences.

This shift reflects the broader trend in contemporary epistemology toward analysing scientific knowledge as situated and processual rather than «fixed» and «universal». As highlighted in recent epistemological research, the focus has shifted toward examining the social processes, material infrastructures, and institutional frameworks through which scientific knowledge is constructed, legitimated, and challenged. Science is not seen yet only as the neutral accumulation of facts: scholars now emphasise the role of collective agency, funding structures, discursive environments, and technological mediation in shaping scientific outputs.

This expanded perspective has been reinforced by a growing body of work across science and technology studies (STS), philosophy of science, and epistemology. Scholars such as Michel Foucault (power/knowledge regimes), Sheila Jasanoff (co-production) or Bruno Latour (Actor-Network Theory) have shown that what is accepted as "scientific fact" is always the result of negotiated processes, involving multiple human and non-human actors, including funding agencies, laboratory instruments, standard-setting bodies, data infrastructures, and discursive norms. These perspectives intersect with recent epistemological approaches that emphasise the contingency

and contextuality of knowledge claims, including work in the contemporary philosophy of science that explores the interplay between evidence, values, and scientific reasoning.

Scientific objectivity is often framed as the outcome of critical interactions among diverse perspectives. It moves beyond purely individual or universal notions to account for the collective and discursive dimensions of knowledge validation. Recent work in philosophy and sociology of science has emphasised that values, discursive norms, and institutional standards shape what is accepted as credible knowledge (Leonelli, 2020; Longino, 2022). This view highlights the importance of “transformative criticism”, a process wherein epistemic diversity and open dialogue enhance the robustness of scientific claims. Complementary research in data epistemology and empirical sociology underscores the influence of infrastructural arrangements, material conditions, and organisational practices in shaping knowledge production. Successful science does not always follow rigid methodological norms. It frequently results from collective negotiation, adaptive reasoning, and empirical pragmatism. These perspectives reinforce the understanding of science as a socially mediated and evolving practice, one that warrants critical scrutiny to assess both its epistemic soundness and societal relevance.

2.2 Situated epistemologies and epistemic diversity

Anthropological approaches to knowledge production offer a powerful complement to the epistemological critiques discussed above. Whether through ethnographic engagement with scientific communities or the broader theorisation of human cognitive and cultural diversity, anthropology brings attention to the plurality of ways in which societies construct, validate, and transmit knowledge.

In particular, two major currents within contemporary anthropology have proved especially influential. The first stems from the tradition of evolutionary and paleoanthropology (Morin, 2016; Richerson & Boyd, 2005; Sterelny, 2012). These approaches prioritise long-term processes and cross-species comparisons to explain how human cognitive and cultural capacities evolved in tandem, emphasising the co-development of language, cooperation, symbolic reasoning, and technology. Their work underlines that many features associated with “scientific reasoning”, such as causal inference, theory of mind, and abstraction, have evolutionary precursors rooted in collective problem-solving, tool use, and symbolic culture. This perspective is further reinforced by Whitehouse’s *Inheritance: The Evolutionary Origins of the Modern World* (2023), which demonstrates how cultural transmission and structures of power shape the continuity of knowledge across generations.

The second current, sometimes described as anarchist or heterodox anthropology, includes authors such as David Graeber, James C. Scott, and Marshall Sahlins (Graeber, 2004; Sahlins, 1972; Scott, 1998). Graeber’s *Fragments of an Anarchist Anthropology* and Scott’s *Seeing Like a State* argue that many forms of knowledge, especially those developed within centralised institutions, systematically obscure or devalue experiential, embodied, and context-specific ways of knowing. Sahlins, in turn, offers a complementary perspective through his work on symbolic exchange and kinship, which underscores the richness of alternative cosmologies and rationalities.

Together, these approaches question the universality of Western scientific epistemologies and highlight the value of cognitive and epistemic diversity. They argue that modern science, rather than being the pinnacle of

rational thought, is a historically and institutionally specific system of knowledge, one that has often marginalised or appropriated other forms of understanding. Such insights resonate with recent debates within Open Science, particularly those emphasising epistemic inclusion and participatory knowledge production.

These anthropological critiques also strengthen the argument that open science must not simply widen access to existing systems of publication and peer review, but should inform policy and institutional debates about what constitutes legitimate knowledge. By emphasising cognitive pluralism and the diversity of epistemic traditions, they support ongoing efforts in open science governance, such as reforming research evaluation, broadening stakeholder inclusion, and valuing community-based and participatory methodologies to existing systems of publication and peer review, but must also recognise and accommodate different modes of validation, evidence, and meaning-making. The inclusion of Indigenous knowledge systems in climate science, the recognition of community-based research in public health, and the adoption of co-design practices in technology development are all examples of how plural epistemologies can enrich and diversify the scientific enterprise. Anthropology thus helps to reveal the socio-cultural foundations of knowledge and the need to foster epistemic justice in scientific practice.

2.3 Sociology of scientific knowledge: The Socio-constructivist paradigm

The sociology of scientific knowledge (SSK) offers a critical framework for examining how scientific knowledge is socially produced, stabilised, and contested. Developed in the 1970s and 1980s, notably by the Edinburgh School (David Bloor, Barry Barnes) and the Bath School (Harry Collins, Trevor Pinch), SSK challenged the traditional view of science as a purely rational or objective endeavor (Barnes, 1974; Bloor, 1976; Collins, 1981). It posits that scientific facts result from socially situated practices, embedded within networks of trust, consensus, and institutional authority. Credibility is not determined solely by empirical validation, but by negotiation of meanings, power dynamics, and the operational norms of scientific communities. Rather than viewing science as isolated from social contexts, SSK asserts that these contexts co-determine what is accepted as valid or true.

One of the foundational contributions was the Strong Programme articulated by Bloor, which proposed that sociological explanations should be applied symmetrically to both successful and failed scientific theories. This symmetry principle rejected the assumption that truth alone explains consensus and instead emphasised empirical inquiry into how agreement is constructed. Barnes, Woolgar, and Collins extended this framework, showing how language, interpretive flexibility, and local laboratory practices shape outcomes.

A key insight of this socio-constructivist paradigm is that scientific knowledge is contingent on negotiation, not merely discovery. Latour and Woolgar's *Laboratory Life* (1979) illustrated how scientific facts emerge from routines of inscription, persuasion, and stabilisation. Facts are not passively revealed by nature but actively constructed through instruments, modeling, documentation, and collective judgment.

This perspective has been further refined by scholars such as Sheila Jasanoff, who developed the concept of co-production to capture how scientific knowledge and social order are mutually constituted (Jasanoff, 2004). The co-productionist approach has informed analyses of citizen science, climate governance, and open science

infrastructures, revealing how scientific agendas are shaped by socio-technical imaginaries, participatory dynamics, and political constraints (Bezuidenhout et al., 2021; Leonelli, 2020).

SSK's relevance to Open Science lies in its insistence on reflexivity. If knowledge is shaped by institutional arrangements and social dynamics, democratising science requires more than open access to data, it demands critical engagement with the structures and actors that define credibility and legitimacy. Open science, from this viewpoint, becomes not just a technical toolkit but a political and epistemological project aimed at restructuring how knowledge is created, validated, and used.

This implies that Open Science should be understood as a socio-political transformation. By foregrounding inclusivity, transparency, and reflexivity, it seeks to democratise research practices, challenge epistemic hierarchies, and enable broader participation from diverse communities of knowledge producers and users.

2.4 Epistemic shifts and the stakes of openness

The perspectives explored in this chapter moved beyond any singular model of how science functions, instead revealing a contested and evolving terrain of knowledge production. What emerges is not a simple shift from objectivity to relativism, but a deeper recognition of science's embeddedness in historical, institutional, and cognitive structures. The authority of scientific knowledge is no longer self-evident or solely grounded in method; it is shaped by negotiation, infrastructures, and power relations that demand scrutiny.

From the performativity of laboratory practices to the situated character of reasoning and the plurality of epistemic cultures, Cognitive sciences, social sciences and humanities have shown that science is not immune to the very dynamics it seeks to explain. These insights do not undermine the value of scientific inquiry but invite more reflexive, inclusive, and adaptive approaches to its governance.

For Open Science, this shift presents both a challenge and an opportunity. It challenges technocratic interpretations that reduce openness to compliance or access alone. But it also opens space for reimagining research as a more participatory, transparent, and plural enterprise, one that accounts for the diverse ways knowledge is constructed, legitimated, and contested. The task, then, is not only to open access to outputs, but to open up the very structures, assumptions, and values that define scientific credibility. It is here that the epistemological reorientation finds its most critical relevance for the future of science.

3. The long road to Open Science: between democratisation and structural inequalities

3.1 The Expansion of Research Output (1945–1970s)

As Chapter 1 showed, the postwar decades reconfigured scientific activity through Cold War rivalry, decolonisation, and developmental state strategies. Massive public investments framed science as modernisation and welfare but also reinforced hierarchies of knowledge production and access. From the 1950s to the 1980s, research expanded globally, entrenching asymmetries between institutions, regions, and epistemic traditions. Despite rapid growth fueled by public funding and geopolitical agendas, openness and participation remained marginal. Legitimacy was tied to centralised control and elite expertise, with research serving defense, industry, and geopolitics. In the U.S., this took shape in the military–industrial–academic complex (Guston, 2022); in Europe and Asia, large-scale institutions such as CERN or export-driven policies emphasised state control and technocratic efficiency (Kodama & Shibata, 2020; Lee, 2013). International cooperation circulated rhetorically, via UNESCO and development initiatives, without ensuring mutual epistemic recognition (Harding, 2011).

Against this background, a core paradox emerged: between the 1950s and 1980s, science was institutionalised on an unprecedented scale as a lever of industrial growth, geopolitical power, and technological sovereignty, yet commitments to openness, inclusion, or participatory governance were largely absent. Dominant orientations prioritised centralised control, elite expertise, and national competitiveness, leaving little space for decentralised or collaborative models. In the U.S., defense-oriented funding entrenched secrecy and hierarchical decision-making (Guston, 2022). Western Europe established centralised systems and transnational institutions such as CERN (1954). In Japan and South Korea, techno-industrial strategies emphasised export-oriented research under strong state guidance (Kodama & Shibata, 2020; Lee, 2013).

It is in this context that the emergence of Open Science in the early 2000s can be seen as a partial rupture with postwar technocracy. Building on reformist and open access initiatives from the 1980s–1990s, such as the creation of arXiv in 1991, which provided one of the first open repositories for physics preprints; the launch of the Public Library of Science (PLOS), which pioneered large-scale, peer-reviewed open access journals in the life sciences; and early experiments in electronic publishing that challenged subscription models, Open Science sought to democratise knowledge through transparency, accessibility, and collaboration. These initiatives demonstrated that digital technologies could support new models of dissemination, lower entry barriers, and question the dominance of commercial publishers. Yet Open Science did not emerge as a unified project. Critical scholars highlight its internal tensions and its inheritance of prior governance contradictions (Fecher & Friesike, 2014; Leonelli, 2021; Mirowski, 2018). Deep disparities in infrastructure and funding, diverging reform visions, and metrics-based policies continue to constrain its democratising potential (Bezuidenhout et al., 2021; Chan et al., 2020).

The legacy of postwar frameworks also helps explain enduring resistance to democratising change. These systems fueled innovation but neglected mechanisms for epistemic inclusion, participatory agenda-setting, or

grassroots experimentation. Although international cooperation, UNESCO's calls for equitable exchange, was prominent, development projects such as the Green Revolution or vaccine programs often relied on top-down models that marginalised local researchers and knowledge systems (Harding, 2011). The exclusion of participation, reflexivity, and democratisation reflected a logic equating legitimacy with centralised control and excellence with exclusivity. Contemporary efforts must therefore confront infrastructures and norms designed to limit, not enable, epistemic inclusion. Recognising that openness was historically sidelined reframes the political and institutional challenges ahead and supports a shift toward openness as a principle of governance that addresses historic exclusions, decentralises expertise, and embeds participation at the core of scientific practice.

3.2 First cracks in the publishing system (1980s–1990s)

The 1980s–1990s marked a turning point in the political economy of publishing. Research output surged, yet access remained limited and increasingly commercialised, revealing a contradiction between the public funding of research and the privatisation of its dissemination. Robert Maxwell's Pergamon Press pioneered a lucrative commercial model; consolidation in the 1980s–1990s left a handful of firms, Elsevier, Springer, Wiley, dominating scholarly communication. By the late 1990s, five major publishers controlled more than half of all research articles (Larivière et al., 2015).

The digital turn intensified these trends. Technologies expanded licensing restrictions and monopolised access as journal prices skyrocketed: 1986–2002 subscriptions rose 227% while library budgets rose 79% (ARL, 2003). “Big deal” bundles locked universities into inflexible contracts, with public and less-resourced institutions canceling subscriptions. A highly asymmetrical value chain persisted: research, writing, peer review, and editorial work were unpaid or publicly funded, while corporate publishers captured value through licensing and databases (Guéron, 2001; Suber, 2012). Resistance emerged within academia: arXiv (1991) and the Budapest Open Access Initiative (2002) promoted preprints, repositories, and public ownership.

Yet Open Access also arose amid New Public Management and neoliberal reforms that evaluated research via performance metrics and audit logics (Lorens, 2012; Shore & Wright, 2015). Entrepreneurial universities (Aalto, Paris-Saclay, Twente) embedded design thinking, IP valorisation, and tech transfer; as Ruano-Borbalan (2023) notes, such configurations often marginalised less market-oriented fields, reinforcing inequalities.

In sum, the late-20th-century publishing crisis exposed economic, epistemic, and institutional contradictions that set the stage for Open Science. As Chapter 5 explores, the challenge extends beyond access to governance: who controls infrastructures, defines legitimacy, and sets the terms of visibility.

3.3 Formalising the Open Science movement: key declarations and frameworks (2000s–2010s)

The early 2000s marked the institutional codification of Open Science principles. While arXiv, created in 1991 by physicist Paul Ginsparg as an open repository for physics preprints, had already challenged commercial publishing dominance in physics and related fields (Larivière et al., 2014), this period extended such models

under overlapping pressures: the falling cost of digital dissemination; public demand for equitable access to publicly funded research (Suber, 2012); and reproducibility crises that eroded trust in scientific results (Ioannidis, 2005). Methodologically, these changes aligned with the rise of evidence-based policymaking, promoted in the late 1990s and early 2000s by the European Commission and the Organisation for Economic Co-operation and Development (OECD), which sought to integrate scientific outputs into socio-economic agendas (Nowotny et al., 2001). At the same time, sociology of science analyses highlighted that attempts to operationalise openness often reproduced institutional and geopolitical asymmetries rather than eliminating them (Hess, 2007; Jasanoff, 2004).

Rather than a unified reform, Open Science emerged as a negotiated assemblage of ideals, imperatives, and contested frameworks. Three landmark declarations crystallised this agenda:

Budapest Open Access Initiative (BOAI, 2002): launched by the Open Society Institute, it called for free, unrestricted online access to peer-reviewed literature. It proposed two complementary strategies, self-archiving of articles by authors and the creation of new open access journals, and reframed communication around global equity, academic freedom, and civic responsibility.

Bethesda Statement on Open Access Publishing (2003): developed in the United States by a meeting of biomedical research funders, publishers, and scientists, it affirmed free availability and reuse rights with proper attribution. It encouraged author-retained copyright and the use of permissive licences (such as Creative Commons) to maximise dissemination.

Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities (2003): initiated by the Max Planck Society in Germany, it broadened the scope of open access to include the humanities and social sciences. It stressed the importance of internet-based infrastructures, interoperability, and institutional support. As of 2024, it has been signed by more than 600 organisations worldwide.

These declarations catalysed alignment around unrestricted access, reusability, and public stewardship. Their impact is visible in the proliferation of repositories, national mandates (e.g., the NIH [National Institutes of Health] Public Access Policy, 2008, in the U.S., requiring NIH-funded research to be deposited in PubMed Central), and evaluation indicators. The OpenDOAR (Directory of Open Access Repositories) grew from fewer than 100 repositories in 2003 to more than 2,500 by 2013. Yet implementation varied: physics, with its established preprint culture, adopted rapidly, while the humanities and some social sciences, where monographs dominate, moved slowly. Funding and infrastructure disparities produced unequal uptake outside the OECD. In 2015, Pinfield et al. reported that 70% of UK universities had open access policies but only 30% had dedicated funding.

Compliance was strongest where funders mandated and financed it; elsewhere, rhetorical support often lacked enforcement and infrastructure. Thus, even in its foundational phase, Open Science reflected and sometimes reproduced existing inequalities. The BOAI, Bethesda, and Berlin statements together constitute the first consolidated wave (2000s–early 2010s) of Open Science: a phase based on declarations and voluntary adoption.

They established the moral and practical vocabulary of openness but left unresolved key questions of sustainability, financial models, and global equity, issues that resurfaced in the second wave of the late 2010s.

3.4 From norms to governance: the Institutionalisation of Open Science (2010s–2020s)

The second wave, beginning in the late 2010s, moved from norms to governance, toward enforceable policies, binding obligations, and performance-based accountability. Drivers included funder concern over subscription-model inequities; the visibility of publisher profit margins (especially during COVID-19); and public demand for transparency as a condition of trust. Plan S (2018), launched by cOAlition S with the European Commission and Science Europe, required that outputs from publicly funded research be openly accessible by 2021, rejecting hybrid journals, mandating compliant platforms, transparent peer review, CC-BY licensing where possible, and cost transparency, while incentivising nonprofit/community platforms. Its rollout sparked debate but forced new contracts and accelerated compliant journals (Schiltz, 2018; Severin et al., 2022).

Concurrently, the European Commission mainstreamed open science across the European Research Area through Horizon 2020 (2014–2020) and Horizon Europe (2021–2027). Open access to publications became mandatory, with strong encouragement (and later requirements) for FAIR-based data managements plans and open science as an evaluation criterion. DG RTD, Science Europe, and the ERC aligned policies, while the European Open Science Cloud (EOSC, 2018) provided a federated environment for data sharing. Universities adopted roadmaps, data stewardship roles, and new assessment frameworks (e.g., CoARA) that decentre journal prestige in favor of transparency, reproducibility, and societal impact, though adoption remains uneven across disciplines.

At the global level, the 2021 UNESCO Recommendation on Open Science articulated a vision grounded in four pillars: open scientific knowledge, open science infrastructures, open engagement with societal actors, and dialogue with other knowledge systems, stressing inclusivity, epistemic diversity, interoperability, and transparency. The Global Research Council, OECD, and G7 reinforced this momentum. Ongoing challenges persist: national fragmentation, resilient publishing oligopolies, and tensions between equity and performance metrics. Concerns about APC-based exclusion have spurred exploration of diamond Open Access models.

In sum, formalisation unfolded in two connected waves. The first (2000s–early 2010s) established principles via declarations and voluntary frameworks; the second (late 2010s–2020s) shifted to regulatory integration, infrastructure design, and system transformation. Openness now functions as both a democratic value and a strategic instrument of research governance.

4. Beyond access: power, platforms, and the fractured promises of Open Science

4.1 Open Science in a competitive and unequal research ecosystem

Open Science has introduced reforms in knowledge sharing, open access mandates, data repositories, participatory methods, yet remains entangled in a research ecosystem marked by asymmetries in infrastructure, governance, and funding. While promising democratisation, it often reproduces hierarchies and market logics, raising doubts about epistemic justice.

Prestige-driven evaluation systems persist. Metrics like the Journal Impact Factor and the h-index dominate hiring, promotion, and funding, disproportionately benefiting elite institutions. Embedded in global databases and bibliometric platforms, they marginalise researchers in Southern and Eastern Europe, Latin America, and parts of Asia and Africa. Horizon Europe's Data Management Plan requirements and the spread of Current Research Information Systems (CRIS) show how administrative compliance can substitute for meaningful openness (Fecher et al., 2023; Power, 1997).

Consolidation of scholarly infrastructure within proprietary ecosystems compounds inequalities. Elsevier's Open Science Hub, Clarivate's Converis, and Springer Nature's Research Square integrate analytics, profiling, and publishing into vertically integrated platforms. They deliver efficiency while deepening dependency on opaque algorithms and commercial standards. As Fecher, Fräßdorf, and Wagner (2023) argue, infrastructural governance increasingly reflects platform capitalism, not commons-based values.

Article Processing Charges (APCs) further stratify. High fees, often >€2,000, shift costs to authors, disadvantaging those without robust support. A 2022 Science Europe report notes that over 70% of open access articles from top European universities appear in high-fee journals. By contrast, SciELO, HAL Afrique, and OpenEdition offer equitable, multilingual alternatives but remain undervalued in rankings and citation systems.

Infrastructure gaps widen divides. Prestigious institutions (ETH Zurich, Max Planck Society, Oxford) fund data stewardship, IP support, and curation; many public universities in Eastern Europe or Sub-Saharan Africa face limited capacity, unstable funding, and fragmented policy alignment. Makerere University's repository struggles with bandwidth and staffing, while Romanian institutions report inconsistent DMP enforcement and limited access to compliant platforms (EUA, 2020; UNESCO, 2021). Even within Europe, initiatives such as Plan S and the European Open Science Cloud (EOSC) have tended to favour research-intensive institutions that already possess the resources and infrastructure to comply; smaller or teaching-oriented universities struggle with repositories, APC budgets, and interoperability. In SSH fields, journal- and dataset-centric OA standards disadvantage books, multimedia, and fieldwork outputs (Bosman & Kramer, 2022).

Market concentration compounds these problems. Five firms, Elsevier, Springer Nature, Wiley, Taylor & Francis, and Sage, control over half of global publishing revenues, consolidating platforms, evaluation tools, and analytics (Fyfe et al., 2017; Larivière et al., 2015). Concentration limits interoperability, standardises performance metrics, and constrains autonomy. Meanwhile, APC models fuel predatory journals. The FTC's 2019 ruling against OMICS

Publishing Group highlighted risks of low-cost, high-volume strategies that exploit precarious researchers; Grudniewicz et al. (2019) warn such practices can discredit Open Access, especially for early career scholars.

Unless these contradictions are confronted, between ideals of openness and market dependency, formal inclusion and substantive capacity, Open Science risks becoming a veneer over inequality. Structural reform should prioritise federated, non-commercial infrastructures ; community governance; equitable funding; and evaluation systems recognising diverse outputs and knowledge ecologies.

4.2 Digital transformation and persistent research asymmetries

As outlined in Chapter 1, Section 1.4 of this report, the digital transformation of the late 20th and early 21st centuries reshaped dissemination, collaboration, and evaluation. It enabled the growth of repositories, preprint platforms, open access journals, and data-sharing practices, but at the same time reinforced asymmetries in capacity, expertise, and influence.

Commercial platforms dominate hosting, indexing, and dissemination. Elsevier, Springer Nature, and Wiley leveraged digital publishing to consolidate position and shape communication's conditions. Elsevier's acquisitions of SSRN, Mendeley, and Bepress expanded vertically integrated ecosystems that create systemic dependencies. A study by Bosman and Kramer (2022) shows 70% of top-cited OA journals rely on infrastructures owned by three multinationals.

Centralisation raises concerns: poor data portability; long-term access contingent on subscriptions or corporate strategy (e.g., Mendeley's 2021 removal of public groups); and compromised autonomy when submission platforms use recommender tools or dashboards steering authors toward high-profit venues.

"Transformative agreements" (e.g., DEAL) tie institutional Open Access policy to proprietary licensing. They increase access but entrench commercial dominance by normalising APC-based publishing and bypassing repositories or diamond OA (Fuchs & Sandoval, 2021). Community-perceived platforms such as ResearchGate and Academia.edu rely on data harvesting, targeted ads, and algorithmic ranking; sustainability and compliance concerns persist .

Metrisation via citation indices, altmetrics, and impact dashboards fuels competitive individualism. JIF, devised as a library tool, still shapes careers. Reliance on journal-based metrics distorts priorities (Brembs, 2020; Moher et al., 2018). Altmetrics are gameable and favor sensationalism. In response, the Leiden Manifesto (Hicks et al., 2015), DORA, and CoARA advocate qualitative, context-sensitive assessment valuing datasets, software, engagement, and team science. Yet implementation is uneven: a 2022 EUA survey found only 30% of European institutions revising criteria, many still leaning on numerical proxies.

Compliance pressures are acute in underfunded ecosystems. The European University Association (EUA, 2021) reports that fewer than 30% of universities in Eastern and Southern Europe have certified repositories or professional data stewardship services. The European Commission's Open Science Monitor (2022) finds that fewer than 40% of institutions in lower-income EU regions have dedicated funding to implement the FAIR principles (Findable, Accessible, Interoperable, Reusable), introduced in 2016 to guide best practices in data

management. While OpenAIRE and the European Open Science Cloud (EOSC) support infrastructures, smaller institutions often lack staffing, IT resources, or digital sovereignty (Fecher et al., 2023). Inclusion initiatives can thus inadvertently deepen exclusion (OpenAIRE, 2022).

The digital shift also intensified predatory publishing. OMICS International, a large open access publisher, was sued by the U.S. Federal Trade Commission (FTC) in 2019 for deceptive practices (FTC v. OMICS, 2019). Despite Jeffrey Beall's List, which catalogued predatory publishers until it was taken offline in 2017 ; see Beall (2013) for an earlier analysis of predatory publishing, and the policies of COPE (Committee on Publication Ethics, founded in 1997 to promote integrity in scholarly publishing), enforcement remains inconsistent. Predatory journals increasingly mimic legitimate outlets (Grudniewicz et al., 2019) Meanwhile, the rapid growth of preprint servers such as bioRxiv (launched in 2013 for biology), SocArXiv (2016 for the social sciences), and PsyArXiv (2016 for psychology) blurred traditional boundaries of peer review. During the COVID-19 pandemic, preprints drew disproportionate media attention (Fraser et al., 2021). Algorithmic filtering and citation recommendation systems further risk entrenching biases toward English-language, well-indexed outlets, widening visibility gaps (Rajan et al., 2022).

Addressing these challenges requires rethinking governance: public investment in open-source platforms ; cross-border regulation; co-designed infrastructures with minority-serving institutions ; and strategies that empower communities to build and sustain their own ecosystems.

4.3 Artificial intelligence and the epistemic reconfiguration of Open Science

AI, computational systems executing tasks requiring human-like cognition, marks an inflection point in knowledge production (Raji et al., 2022; UNESCO, 2023; Whittlestone et al., 2021). Within open science, AI functions both instrumentally and transformatively, reshaping epistemological and institutional architectures of legitimacy, trust, and accountability.

This trajectory builds on the openness tradition seeded by the GNU Project (1983) and the Open Source Initiative (1998), which emphasised transparency, reuse, and collective governance (Benkler, 2006; Kelty, 2008). However, contemporary AI, particularly large language models (LLMs) and generative systems, introduces black-box reasoning and new asymmetries of control. While accelerating hypothesis generation, classification, and synthesis, AI also raises concerns about reproducibility, bias, and the delegation of epistemic authority to opaque systems (Ananny & Crawford, 2018) Moreover, AI's entanglement with proprietary data and compute monopolies intensifies worries about epistemic sovereignty (Bender et al., 2021; Birhane, 2021).

In practice, the impact of AI is already visible. GPT-4 and its successors are embedded in writing assistants (e.g., SciSpace, Elicit), citation platforms (e.g., Semantic Scholar), and peer review tools (e.g., ReviewerFinder). AlphaFold2 revolutionised protein structure prediction (Jumper et al., 2021). LLMs now support literature discovery and multilingual summaries (van Dis et al., 2023). Editorial offices and funding agencies experiment with AI for triage and portfolio analysis. The benefits of speed and scale coexist with serious risks of opacity, accountability gaps, and potential deskilling of researchers.

The challenges are significant. Dependence on biased or proprietary datasets undermines generalisability and equity (Birhane, 2023). Opaqueness complicates replication, while infrastructural dependency on corporate providers limits autonomy. Responding to these risks, the EU's AI Act and UNESCO's 2023 Recommendation both stress the importance of open, explainable, and ethically governed AI. Yet the metricised governance of research increasingly embeds algorithmic logic, prompting scholars to warn of techno-managerial reductionism (Croucher et al., 2023; Daston, 2022).

Still, AI can contribute to advancing open science if developed under robust public governance and participatory design. Initiatives such as the European Open Science Cloud (EOSC) and GAIA-X aim to host transparent, interoperable tools; community-driven models like OpenML and the Allen Institute's open NLP resources illustrate non-commercial alternatives. AI can also lower barriers to participation through translation, summarisation, and exploratory analysis, as seen in the EMBO Journal's AI-assisted reviews and Hugging Face's open repositories.

Realising this potential requires coherent policies for inclusivity, reproducibility, and oversight. This includes sustained support for open-source AI, investment in public data infrastructures, programmes for algorithmic literacy, and transparency mandates for AI-assisted outputs. Such measures, coordinated across borders, are essential to avoid a fractured landscape in which only a few regions set the norms for global science.

4.4 Critical perspectives and ongoing debates

Despite growing institutionalisation, Open Science remains contested. Critics warn that "openness" can be co-opted by dominant actors with concentrated resources, reinforcing inequalities rather than redressing them. Infrastructures, platforms, and assessment systems demand high levels of digital, financial, and linguistic capital (Bezuidenhout et al., 2021; Chan et al., 2020). This dynamic can amount to epistemic extractivism, where less-resourced researchers share data without reaping commensurate benefits or shaping participation norms.

Yet counter-examples illustrate the inclusive potential of Open Science when coupled with investment and training. The African Open Science Platform (AOSP) works to build capacity and interoperable systems across the continent. Initiatives such as SciELO and RedALyC promote open access without article processing charges (APCs), demonstrating viable alternatives to commercial publishing models.

A central debate concerns the commodification of scholarly labour. APC-based open access shifts costs from readers to authors, disadvantaging early career scholars and those outside elite systems. Commercial control of infrastructures persists (Lawson et al., 2020; Piwowar et al., 2018). At the same time, reform paths are visible in transformative agreements (e.g., DEAL in Germany, Bibsam in Sweden, Plan S in Europe) and in diamond open access models supported by UNESCO and Science Europe.

Epistemologically, assumptions about transparency, reproducibility, and access are historically situated and vary significantly across disciplines. Qualitative fields, for example, face ethical constraints on sharing sensitive data. Still, frameworks such as the TOP (Transparency and Openness Promotion) Guidelines and Open Science Badges allow flexible adoption. Journals like *Psychological Science* and infrastructures like the Open Science Framework (OSF) demonstrate how such practices can be implemented in adaptable ways.

Reform of research evaluation also plays a crucial role. Initiatives such as DORA (San Francisco Declaration on Research Assessment), the Leiden Manifesto, and CoARA (Coalition for Advancing Research Assessment) aim to replace simplistic metrics with more qualitative and inclusive approaches. Implementation remains uneven, but examples such as narrative CVs introduced by the French ANR, the UK's REF 2021 impact case studies, and the Dutch Recognition and Rewards programme show that systemic change is feasible.

Open Science is not monolithic; definitions and implementations vary across disciplines, institutions, and regions. Current debates on AI, data sovereignty, and Indigenous data governance underscore its evolving nature. Its future hinges on integrating critiques, supporting experimentation, and respecting diverse knowledge practices across the global academic community.

5. Open Science under pressure

5.1 Critical moments

The narrative of Open Science as a linear march toward inclusivity obscures its contested, crisis-driven development. What appears as a global movement is instead the product of successive disruptions, economic, political, and ecological, that pressured research systems and exposed fractures in governance. Recent analyses reinforce this perspective: Thibault (2023) describes how Open Science 2.0 has emerged less through steady diffusion than through moments of rupture; Soliman (2025) shows that credibility crises in psychology spurred dramatic policy uptake; and Hosseini (2025) highlights how the rise of generative AI disrupted norms of transparency and governance. Together, these studies underscore that Open Science evolved in reaction to shocks and crises rather than as a smooth, linear process.

The 2008 financial crisis marked the first of these turning points, reshaping policy orientation in Europe and North America. Shrinking budgets and rising accountability demands led governments to insist that publicly funded science be open, transparent, and aligned with socio-economic goals. Policy frameworks such as Horizon 2020 (European Commission, 2013) and the OECD Recommendation on Public Sector Information (OECD, 2008) emphasised openness, reuse, and impact. Openness became bound to metrics, data management plans, and access mandates. Yet these requirements often burdened underfunded institutions, turning ideals into bureaucratic compliance.

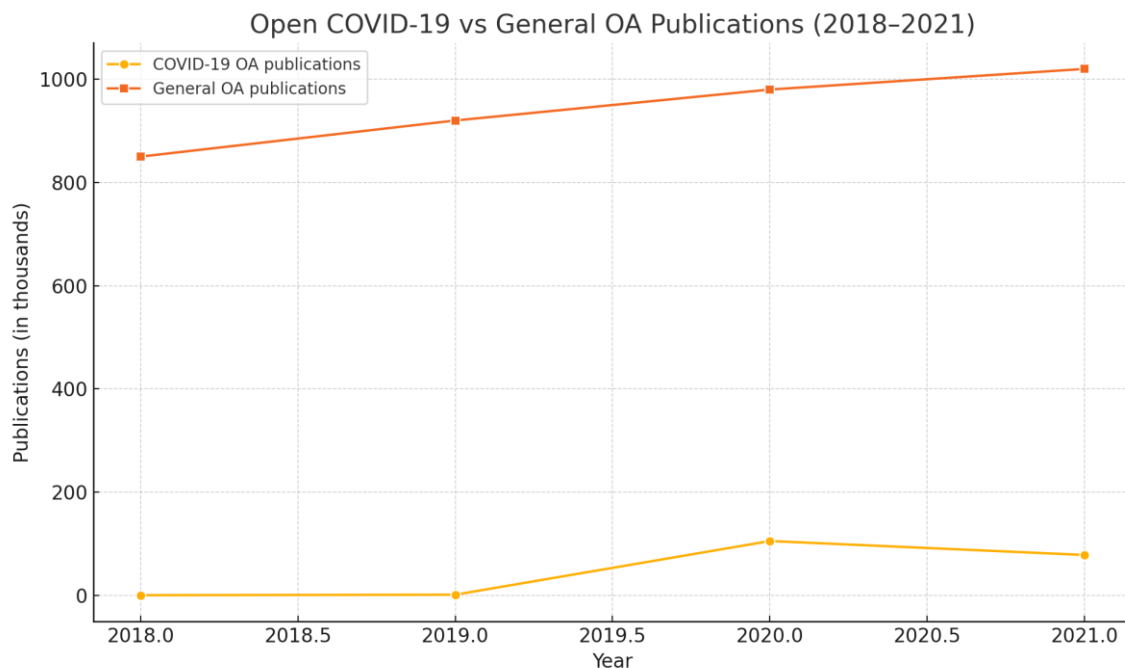
A second major disruption came with Plan S (2018), designed to dismantle the subscription model. By centring Article Processing Charges (APCs), it deepened inequalities: Western institutions absorbed costs through national agreements, while others, particularly in Eastern Europe, Latin America, and Africa, were marginalised. Hybrid journals and “transformative agreements” reinforced dominant publishers. The exclusion shifted from paywalls to pay-to-publish. Preprint platforms such as arXiv and bioRxiv expanded, but language bias and limited recognition persisted (Fecher & Friesike, 2014; Leonelli, 2021; Mirowski, 2018).

COVID-19 further accelerated openness. In 2020, over 105,000 COVID-related papers appeared in open access (Brainard, 2021; Else, 2020; Fraser et al., 2021). Paywalls dropped, datasets opened, and preprints dominated. Yet contradictions quickly emerged: while rhetoric of solidarity thrived, vaccine access and biotech data remained concentrated. COVAX faltered, TRIPS restrictions endured, and many widely cited articles were unreviewed preprints, amplifying misinformation. Journals fast-tracked papers, exposing governance gaps. As Soliman (2025) and Hosseini (2025) stress, such episodes illustrate how openness proved both vital and risky, catalysing change but also revealing deep vulnerabilities in infrastructures and governance logics.

Figure 1: Open COVID-19 vs General Open Access Publications (2018–2021)

This figure illustrates the dramatic increase in open access publications related to COVID-19 during the pandemic compared to the general trend in open access scientific publications between 2018 and 2021. The year 2020 saw a massive spike in COVID-related publications, highlighting how global crises can catalyse accelerated

dissemination of research. Despite this surge, structural limitations, such as inequities in access to knowledge production and reliance on dominant publishing platforms, persisted.



Sources:

Fraser, N., Brierley, L., Dey, G., Polka, J. K., Pálffy, M., Nanni, F., & Coates, J. A. (2021). The evolving role of preprints in the dissemination of COVID-19 research and their impact on the science communication landscape. *PLOS Biology*, 19(4), e3000959.

Else, H. (2020). How a torrent of COVID science changed research publishing, in seven charts. *Nature*, 588(7839), 553–553.

Brainard, J. (2021). Scientists are drowning in COVID-19 papers. Can new tools keep them afloat? *Science*, 368(6494), 924–925.

UNESCO. (2021). *UNESCO Recommendation on Open Science*. Paris: UNESCO Publishing.

The pandemic showed that crises catalyse accelerated openness, but also highlight fragilities. Openness served efficiency and visibility more than justice. Further pressures, such as the war in Ukraine and global energy volatility, exposed dependencies on Western infrastructures, while China and India built sovereign platforms. These dynamics turned Open Science into a geopolitical field (Shibata et al., 2023). UNESCO's 2021 Recommendation promoted inclusivity, yet national uptake often remained technical rather than structural.

Across crises, a pattern emerges: Open Science is reconfigured under pressure. Gains in speed and dissemination rarely yield lasting governance reform. Openness risks becoming a technocratic instrument, responsive but not transformative. Infrastructures controlled by Elsevier, SpringerNature, and Clarivate shape visibility and funding. Metrics and APIs become gateways of participation. Democratisation requires not just openness but rethinking ownership and authority, issues explored further in Chapter 6.2.

5.2 Environmental crises and the imperative of open collaboration

The ecological crisis, climate disruption, biodiversity loss, and resource degradation, reshapes the very conditions of knowledge production. These systemic risks (Beck, 1992; Steffen et al., 2015) reveal the inadequacy

of disciplinary, proprietary, and nationally bounded models. As a result, calls for open, inclusive, and transdisciplinary collaboration have intensified, though practice often lags behind aspiration.

Global platforms such as the IPCC (Intergovernmental Panel on Climate Change) and IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) integrate open review processes, multilingual access, and recognition of Indigenous knowledge. Yet they remain criticised for their centralised and technocratic structures (Jasanoff, 2007). According to UNEP data, only 46% of member states had fully accessible environmental monitoring systems by 2023, underscoring persistent gaps. Still, examples of more accessible models exist: Copernicus provides free satellite data for environmental monitoring; citizen science projects such as Luftdaten.info, Biodiversity4All, and Ground Truth 2.0 demonstrate how grassroots initiatives can generate data that informs policy (Haklay et al., 2018; European Commission, 2018). Horizon Europe further embeds co-creation and FAIR (Findable, Accessible, Interoperable, Reusable) data standards in its climate and oceans Missions, though scholars warn these efforts risk tokenism without sustained investment in under-resourced regions (Bocquet, 2021).

Three rationales underscore the need for open collaboration in addressing ecological crises. First, ecological complexity demands diverse knowledge systems. Second, the legitimacy of decisions depends on transparency. Third, persistent inequalities leave vulnerable communities under-equipped to shape solutions. Jasanoff's (2007) notion of "technologies of humility" highlights the importance of reflexivity and inclusion in navigating uncertainty. Hybrid infrastructures such as the Climate Risk Atlas and PREPdata illustrate how distributed, accountable science can function in practice. In today's context, open collaboration is not optional but essential, both for legitimacy and for building shared, sustainable futures.

5.3 The political economy of Open Science

Beneath its normative appeal, Open Science operates within a political economy shaped by marketisation, globalisation, and competition. It is strongly influenced by academic capitalism (Popp Berman, 2022; Slaughter & Rhoades, 2020), managerialism, and transnational metrics regimes. In this context, openness is redefined within hierarchies and asymmetries rather than dismantling them.

First, the balance between knowledge as a public good and market logics remains unstable. Analyses by Altbach, Reisberg, and Rumbley (2009), Brint (2018), and Ruano-Borbalan (2022, 2025) show how performance cultures and institutional branding reshape Open Science, often reinforcing exclusion. Open access shifts costs to producers, disadvantaging smaller institutions. Plan S, while ambitious, benefits elite universities and consortia with negotiation capacity, leaving others constrained.

Second, infrastructures are dominated by data monopolies. Elsevier, SpringerNature, and Clarivate control bibliometrics and analytics, embedding proprietary standards into research evaluation. These platforms act as gatekeepers, dictating visibility. Public initiatives such as the European Open Science Cloud (EOSC) and France's Recherche Data Gouv provide counterweights but risk replicating managerial capture if not carefully governed.

Third, inequalities persist globally. Sub-Saharan Africa, Latin America, and Southeast Asia continue to face barriers in infrastructure, language, and policy influence. Platforms like AmeliCA and SciELO build regional

ecosystems but remain marginal in global metrics regimes. APC models disadvantage scholars without grants, further entrenching disparities. Geopolitical shifts, such as China's 14th Five-Year Plan and the U.S. CHIPS and Science Act, frame science within rivalry, limiting commons-based approaches. Selective openness undermines pluralism and equitable participation.

Finally, Open Science often mirrors managerial logics. Studies in the *Oxford Handbook of Higher Education Systems* (Whitley, Gläser, & Engwall, 2018) and the *Handbook of Science and Technology Studies* (Felt et al., 2017) show how KPIs, rankings, and evaluations embed openness into audit cultures. National and regional frameworks, such as the UK's REF, France's HCERES, and Germany's Exzellenzinitiative, emphasise visibility and funding competitiveness. Moedas et al. (2023) and Dierkes & Lemke (2022) demonstrate how openness is co-opted to reinforce prestige. Commercial platforms increasingly act as de facto regulators (Cañete & Laakso, 2024; Montgomery et al., 2023). Even reformist initiatives like Plan S or EOSC may reproduce centralisation (Bezuidenhout et al., 2023).

In sum, the political economy of Open Science reveals enduring paradoxes: promises of democratisation entangled with market consolidation, geopolitical rivalry, and stratification. Reform requires reasserting science as a public good through non-commercial infrastructures, inclusive funding, and plural publishing models. Without structural change, openness risks entrenching exclusion under a new guise.

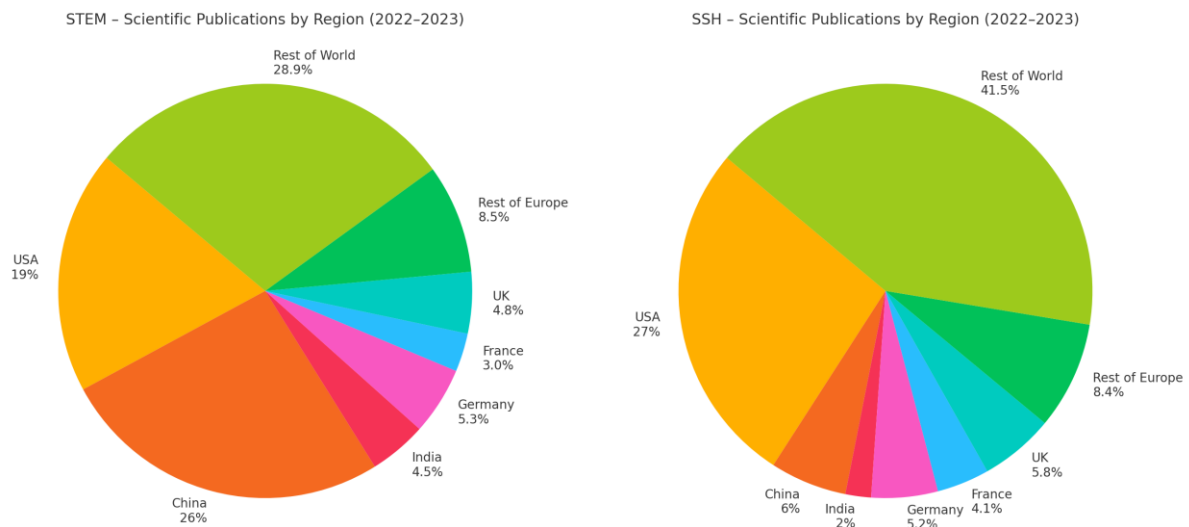
6. Revolutionising scientific communication and evaluation

The ambition to reform scientific publishing has long been a core component of the Open Science agenda. Initially driven by dissatisfaction with the paywall economy of commercial academic publishing (see Chapter 1), the movement has expanded to challenge the legitimacy, effectiveness, and equity of traditional models of research communication and assessment. Yet despite strong normative and policy momentum, this revolution remains incomplete and structurally constrained. As discussed in Chapter 5.1, which highlights infrastructural asymmetries in global research ecosystems, and in Chapter 5.3, which analyses the political economy of marketisation and metrics regimes, the architecture of Open Science is still dominated by commercial platforms and proprietary evaluation tools. These structures shape visibility, access, and assessment in ways that reproduce exclusion. The techno-managerial logic underpinning performance-based funding and reputational competition, already critiqued in the political economy of Open Science, finds an especially acute expression in publishing and research assessment, where oligopolistic actors, misaligned incentives, and infrastructural dependencies entrench inequalities and limit systemic change.

Figure 2: Proportional Scientific Publications by Region and Discipline (2022–2023, Expanded Europe)

This combined figure compares the proportional distribution of scientific publications in two major disciplinary domains, STEM (Science, Technology, Engineering, Mathematics) and SSH (Social Sciences and Humanities), by major world regions for the year 2022–2023. It highlights striking divergences in regional concentration and disciplinary investment. While China leads in STEM output (26%), its share in SSH remains minimal (6%), reflecting the country's prioritisation of technological and industrial research aligned with its national development strategy (14th Five-Year Plan). Conversely, the USA maintains a strong presence in both domains, but especially in SSH (27%), where its legacy institutions and broad funding base support a large corpus of scholarly output. European countries, though collectively significant, reveal fragmentation: the UK shows a higher SSH share than STEM, while Germany and France maintain more balanced outputs. Notably, the "Rest of the World" category dominates SSH output (41.5%), which includes numerous low- and middle-income countries publishing in local or regional venues not captured by standard indexes. This underlines ongoing structural inequalities in global visibility and resource allocation, as well as the need for inclusive metrics and platforms.

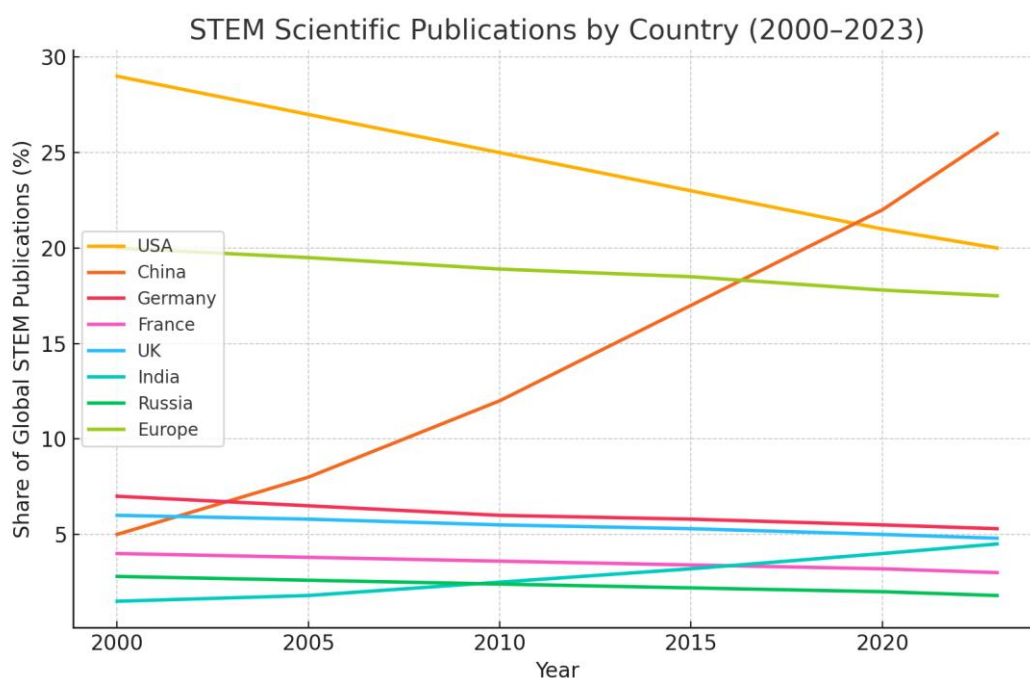
Proportional Scientific Publications by Region and Discipline (2022–2023, Expanded Europe)



Sources: UNESCO Science Report (2021), OECD Main Science and Technology Indicators (2023), Elsevier Scopus (2023), Clarivate Web of Science (2023), ISC Monitoring Reports (2023), OPERAS Data (2022).

Figure 3: Long-Term Evolution of Scientific Publications by Region and Discipline (2000–2023)

This figure complements previous pie charts by presenting a longitudinal perspective (2000–2023) on the global evolution of scientific publication outputs. It reveals how China’s exponential growth in STEM fields has dramatically reshaped the landscape, overtaking the US in total volume around 2018. Meanwhile, the relative share of Europe (aggregated) has remained stable but fragmented, with the UK, Germany, and France contributing distinctly. In Social Sciences and Humanities (SSH), the rise is far less concentrated, with the US maintaining a lead, Europe diversifying its outputs, and the Rest of the World increasing its presence, particularly in multilingual and non-indexed formats. The data confirm the increasing disciplinary polarisation: STEM fields are globally converging around large producers, while SSH remains regionally embedded and underrepresented in global metrics. This visualisation underscores the urgent need to develop more pluralistic infrastructures and recognition systems for SSH outputs across the globe.



Sources : UNESCO Science Report (2021), OECD MSTI (2023), Elsevier Scopus (2023), Clarivate Web of Science (2023), ISC Monitoring Reports (2023).

6.1 Structural lock-ins and publishing oligopolies

The persistence of monopolistic publishing practices remains a structurally resilient obstacle to democratising knowledge. These practices stem not only from market concentration but also from the deep entanglement of commercial infrastructures with mechanisms of academic value attribution. Over two decades, consolidation has produced four dominant conglomerates, Elsevier (RELX), Springer Nature, Wiley, and Taylor & Francis (Informa), which account for over 62% of journal publishing revenue (EUA, 2023). Their hegemony extends beyond journals to submission platforms (e.g., Editorial Manager), citation databases (Scopus, Web of Science/Clarivate), and bibliometric analytics (SciVal, Journal Citation Reports), creating systemic lock-in: universities and researchers rely on platforms that simultaneously manage submissions, measure impact, and define visibility. This multi-layered entrenchment generates conflicts of interest, where the same actors profit both from publishing and from evaluating it.

The rise of Article Processing Charges (APCs) for open access has deepened inequalities. OpenAPC (2022) shows that more than 60% of German APC expenditures go to the top four publishers. Rather than reducing concentration, APC-based open access shifts costs to authors and institutions, benefiting well-funded universities while excluding others from visibility.

Budgets reflect this imbalance: SPARC Europe (2022) reports that 75% of European university library acquisitions remain tied to “Big Deal” bundles, diverting funds from smaller, non-commercial, or community-based publishers and undermining bibliodiversity.

Crucially, publishing oligopolies also control the epistemic infrastructure of recognition. Proprietary metrics such as the Journal Impact Factor (JIF), h-index, and citation counts, generated within Scopus and Web of Science, underpin research assessment, rankings, and funding. These metrics privilege English-language journals, fast-citing disciplines (especially STEM), and outlets owned by dominant publishers. UNESCO (2021) notes that over 70% of peer-reviewed journals published in Africa and Latin America are not indexed in Scopus or Web of Science, rendering them largely invisible in global evaluations.

This exclusion is built into the citation ecosystem. Research addressing local challenges, published in languages other than English, or using interdisciplinary/participatory methods often falls outside dominant indexing practices, devaluing non-mainstream knowledge. Scholars in the Global South or in less-resourced disciplines are pressured to conform to dominant standards to secure funding, employment, or prestige.

Consequences are visible in distorted research agendas. As Montgomery et al. (2021) observe, “visibility capitalism” incentivises strategies that maximise metrics rather than epistemic or societal relevance. The feedback loop between metrics, rankings, and funding disciplines researchers into publishing in high-impact journals, regardless of local needs or linguistic diversity.

Community-led platforms challenge this configuration. SciELO (FAPESP, since 1998) hosts more than 1,300 journals from Latin America, Spain, Portugal, and South Africa with fee-free full-text access. RedALyC (since 2003, UAEM) covers more than 1,000 Ibero-American journals, integrating metadata and open standards for South–South exchange. The Open Library of Humanities (OLH, 2015) publishes more than 30 SSH journals funded by a 300-library consortium, offering diamond Open Access with scholar-led governance. Despite their proven viability, these platforms remain marginalised in rankings and are under-resourced relative to commercial giants.

A critical barrier lies in the epistemic framing of quality: indexing status and impact metrics are treated as proxies for excellence in frameworks such as the UK’s REF, France’s HCERES, or Germany’s Exzellenzstrategie. These frameworks embed indicators linked to publisher-owned databases, reinforcing cycles in which commercial control becomes indistinguishable from academic prestige.

Table 1: Market Share and Infrastructure Control of Major Academic Publishers (2023)

Publisher	Share of Global Journal Revenue (2023)	Share of Indexed Journals in STEM	Major Services Owned
Elsevier	34%	39%	Scopus, SciVal, Editorial Manager
SpringerNature	13%	15%	Nature Index, SNAPP
Wiley	9%	10%	Wiley Online Library
Taylor & Francis	6%	7%	Routledge, F1000

Sources: EUA 2023; RELX 2023 Annual Report; SPARC Europe 2022.

The convergence of publishing, indexing, and evaluation constitutes a regime of “academic capitalism.” As Slaughter and Rhoades (2004) and Münch (2020) document, the market-oriented transformation of higher education has enabled private metrics to permeate public governance. Universities are managed as competitive enterprises; publishing functions as communication mechanism, institutional branding, and career currency. This is not merely about cost or access, but about governance. Concentrated publishing power plus metricised value narrows epistemic diversity, commodifies visibility, and structurally excludes alternative voices. Addressing this requires regulatory reform and a redefinition of what counts as knowledge and value.

6.2 Reforming the system: towards plural and public infrastructures

The monopolistic hold of commercial publishers on scholarly communication has prompted a range of reform efforts across Europe and internationally. While the consolidation of publishing power continues to pose a structural barrier to equity and diversity in knowledge dissemination, an expanding set of initiatives now seek to challenge this dominance by constructing alternative, plural, and publicly governed infrastructures. These efforts vary in scope and ambition, from transformative agreements negotiated by consortia of universities to grassroots diamond Open Access platforms. Yet they share a common objective: to reclaim scholarly communication as a public good (UNESCO, 2021).

One of the most emblematic examples is Germany’s Projekt DEAL. Launched in 2014 and coordinated by the Alliance of Science Organisations and the German Rectors’ Conference (HRK), the project aims to redirect public expenditure from subscription-based models to open access publishing. Through national-level “publish and read” agreements with Wiley (2019), Springer Nature (2020), and Elsevier (2023), DEAL ensures that affiliated researchers can publish open access without paying individual APCs while securing full access to the publishers’ journal portfolios (<https://www.projekt-deal.de/>). The initiative represents a tactical reallocation of institutional power and has inspired similar models in the Netherlands (Universiteiten van Nederland: https://www.universiteitenvannederland.nl/en_GB/open-access), France (Couperin: <https://couperin.org/>), and the UK (Jisc: <https://www.jisc.ac.uk/open-access>).

Table 2: National Transformative Agreements in Europe (2023)

This table compares national-level transformative agreements signed by university consortia across several European countries. It highlights the lead coordinating agency, major publishers involved, and estimated annual financial commitments. These agreements represent attempts to negotiate publish-and-read contracts that enable open access publication for affiliated researchers.

Country	Lead Agency	Publishers Involved	Estimated Annual Spend (€)
Germany	Projekt DEAL / HRK	Wiley, Springer Nature, Elsevier	>€180 million

Netherlands	Universiteiten van Nederland	Elsevier, Springer Nature, Wiley	€25–30 million
France	Couperin Consortium	Elsevier, Springer Nature, Wiley, others	€40 million
UK	Jisc Collections	Elsevier, Wiley, Springer Nature, Taylor & Francis	€60–70 million
Sweden	Bibsam Consortium	Elsevier, Wiley, Springer Nature	€20 million

Sources: European University Association (EUA, 2023); ESAC Transformative Agreement Registry (<https://esac-initiative.org/>)

These agreements are controversial: while promoting horizontal equity nationally, they may entrench the Big Four via expensive multi-year contracts, opaque pricing, and exclusion of smaller or non-commercial publishers (Morrison, 2020; Schimmer, Geschuhn & Vogler, 2022).

A more radical departure is diamond Open Access: no fees for authors or readers, funded by libraries, institutions, or public agencies. Examples include OLH (<https://www.openlibhums.org/>), Épisciences and OpenEdition (France, <https://www.openedition.org/>), SciELO (<https://scielo.org/>) and RedALyC (<https://www.redalyc.org/>) in Latin America, and Janeway (OLH's open-source platform). These platforms prioritise transparency, multilingualism, and epistemic inclusion but remain underfunded and marginalised in global evaluation systems (Adema & Stone, 2023).

Public platforms complement these efforts. France's HAL (<https://hal.archives-ouvertes.fr/>) and Recherche Data Gouv (<https://recherche.data.gouv.fr/>) provide state-managed infrastructures for publications and datasets. AmeliCA (<https://www.amelica.org/>) builds a South–South model centred on sovereignty, multilingualism, and non-commercial circulation.

Table 3: Public and Community-led Knowledge Infrastructures (2023)

This table compares key public and community-based Open Access infrastructures, focusing on their geographic scope, funding bodies, number of journals or datasets hosted, Open Access models (e.g., diamond OA, green OA), and their inclusion in national or international research evaluation systems. These initiatives represent viable alternatives to commercial publishing systems and reflect diverse epistemic and governance models.

Platform	Country / Region	Funders / Sponsors	Journals Covered	OA Model	Included in Evaluation?
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HAL	France	CNRS	~190,000 deposits (all disciplines)	Repository (Green OA)	Partially (France)
Recherche Data Gouv	France	French Ministry of Research	Multidisciplinary (datasets)	Repository / FAIR data	No
AmeliCA	Latin America	UNESCO, CLACSO, RedALyC	400+ journals	Diamond OA	Rarely
SciELO	Latin America	FAPESP, CNPq	1,300+ journals	Diamond OA	Partially
RedALyC	Latin America	UAEM, CONACYT	1,000+ journals	Diamond OA	Rarely
OpenEdition	France	CNRS, Aix-Marseille Univ.	500+ journals/books	Diamond OA	Partially
OLH	UK / Intl.	Library consortium	30+ journals	Diamond OA	No

Sources: HAL (<https://hal.archives-ouvertes.fr/>), Recherche Data Gouv (<https://recherche.data.gouv.fr/>), AmeliCA (<https://www.amelica.org/>), OpenEdition (<https://www.openedition.org/>), SciELO (<https://scielo.org/>), RedALyC (<https://www.redalyc.org/>), OLH (<https://www.openlibhums.org/>)

Policy frameworks have increasingly responded to these developments. The European Commission's Horizon Europe programme now includes mandates for FAIR data, open repositories, and support for initiatives such as OPERAS (<https://operas-eu.org/>) and the European Open Science Cloud (EOSC, <https://eosc-portal.eu/>). At the governance level, the Coalition for Advancing Research Assessment (CoARA, <https://coara.eu/>), launched in 2022 and now endorsed by over 600 institutions, calls for the decoupling of research evaluation from journal metrics and the adoption of broader, context-sensitive and qualitative indicators.

Table 4: Key international and European initiatives for research assessment reform

This table summarises selected major initiatives that aim to transform academic research assessment and publishing infrastructures. These efforts reflect growing international consensus on the need to decentre citation-based metrics and support non-commercial, inclusive platforms for Open Science.

Initiative	Key Features	Lead Organisation(s)	Website
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CoARA (2022)	Promotes institutional change in research assessment; emphasises qualitative evaluation and de-emphasising journal-based metrics.	European Commission, EUA, Science Europe	https://coara.eu
UNESCO Recommendation on Open Science (2021)	Global framework encouraging inclusive, equitable, and community-driven Open Science practices.	UNESCO	https://unesdoc.unesco.org/ark:/48223/pf0000379949
Global Research Council & OECD Guidelines	Principles for responsible research evaluation and support for open infrastructures and FAIR data.	GRC, OECD	https://www.globalresearchcouncil.org
OpenAlex	Open-source bibliometric graph and discovery platform designed as an alternative to proprietary citation databases.	OurResearch	https://openalex.org
Initiative for Open Abstracts (I4OA)	Encourages publishers to make abstracts openly available to improve discovery and transparency.	Crossref, OurResearch	https://i4oa.org
RedALyC / SciELO / AmeliCA	Latin American and Southern consortia supporting non-commercial, multilingual Open Access publishing.	CLACSO, public universities, national research councils	https://www.redalyc.org / https://scielo.org / https://amelica.org

UNESCO's 2021 Recommendation on Open Science offers a global normative framework, emphasising inclusiveness, equity, multilingualism, and open participation (<https://unesdoc.unesco.org/ark:/48223/pf0000378841>). It explicitly recommends the integration of Indigenous knowledge, citizen science, and non-dominant epistemologies into Open Science strategies. These principles are echoed in the OECD-GRC guidelines (<https://www.oecd.org/sti/inno/global-research-council.htm>), which stress the importance of participatory governance, shared funding models, and systemic reform.

Nevertheless, significant tensions remain. National-level reforms often struggle to match the scale and integration of commercial platforms. Public infrastructures face chronic underinvestment, and their interoperability remains partial. Moreover, the persistence of citation-based evaluation systems, anchored in Scopus and Web of Science, undermines the visibility and legitimacy of community-led publishing efforts. As long as funders and universities continue to tie recognition and resource allocation to proprietary metrics, Open Access will remain trapped within a narrow, performance-driven logic.

Reforming scholarly communication thus requires more than technical fixes. It demands a reconfiguration of academic governance, a redistribution of infrastructural power, and a redefinition of excellence that is attentive to linguistic, epistemic, and regional diversity. In this context, community-led infrastructures and international

policy coalitions offer not just technological alternatives, but new imaginaries, concrete proposals for a more democratic, plural, and inclusive global research ecosystem.

6.3 Big Deals: locking institutions into dependency

“Big Deals”, bundled subscriptions negotiated by publishers with university consortia, were introduced in the early 2000s as pragmatic responses to spiralling journal costs. By offering broad portfolio access at negotiated prices, they promised budgetary stability and improved access. Yet, as shown in Sections 6.1 and 6.2, they have become instruments of infrastructural dependency, reinforcing publishers’ dominance and constraining public capacity to develop autonomous dissemination models.

The consolidation of the market into a handful of firms, Elsevier, Springer Nature, Wiley, and Taylor & Francis, has allowed publishers to leverage Big Deals to maintain lock-in, suppress price transparency, and undermine pluralism. Adding SAGE, five major commercial publishers now account for over 75% of articles indexed in leading databases (Dimensions and Clarivate, 2023). SPARC Europe (2022) further reports that in many countries more than 80% of library serials budgets are concentrated in such bundles, often under non-disclosure clauses.

This opacity misallocates resources: bloated packages with low-use titles divert funds away from local journals, monographs, or open infrastructures. For less well-resourced institutions, the high costs make participation impossible, deepening global inequalities. The prestige–evaluation–access triad sustains Big Deals even when their practical utility is questionable.

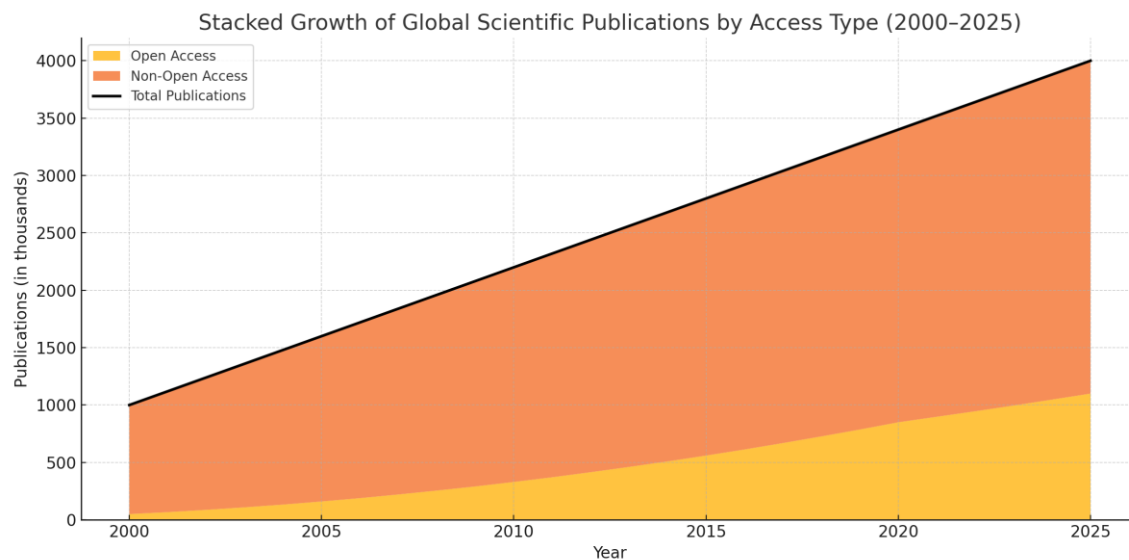
Many so-called transformative agreements reproduce these logics. Germany’s DEAL contracts with Wiley and Springer Nature, while advancing Open Access, retain opacity and cost escalation; average APCs exceed €2,750 (Schimmer, Geschuhn & Vogler, 2022), raising concerns of sustainability and equity, particularly in the social sciences and humanities. Both EUA (2023) and COAR (2022) warn that such models privilege well-funded institutions and risk further fragmenting the European Research Area.

In low- and middle-income regions, including much of Africa, South Asia, and Latin America, Big Deals remain largely inaccessible. UNESCO (2022) documents persistent disparities in licensing and digital infrastructure. Programmes such as Research4Life (AGORA, GOALI, Hinari, OARE) extend access in more than 125 countries (Research4Life, 2023; UNESCO, 2022), yet they provide limited publishing support, depend on voluntary participation, and lack preservation guarantees or integration of local knowledge systems and multilingual outputs (Bezuidenhout et al., 2023).

Some academic systems have resisted these dynamics. The University of California terminated Elsevier subscriptions in 2019; Sweden’s Bibsam Consortium and Norway’s Unit took similar steps in 2018–2019. Although renegotiations followed, these actions demonstrated that universities and consortia possess leverage to demand fairer terms, greater transparency, and stronger public oversight.

Figure 4: stacked Growth of Global Scientific Publications by Access Type (2000–2025)

This area chart shows the estimated evolution of global scientific publications from 2000 to 2025, split between Open Access and Non-Open Access outputs. The visual alignment ensures that the total number of publications is exactly equal to the sum of its two components at each time point. The growth of Open Access has been steady and significant, yet Non-Open Access continues to represent a large portion of total scientific production, particularly in commercial and subscription-based publishing contexts.



Sources:

UNESCO (2021). UNESCO Recommendation on Open Science. Paris: UNESCO Publishing.

Piwohar, H., Priem, J., et al. (2018). The state of OA: a large-scale analysis of the prevalence and impact of Open Access articles. PeerJ, 6, e4375.

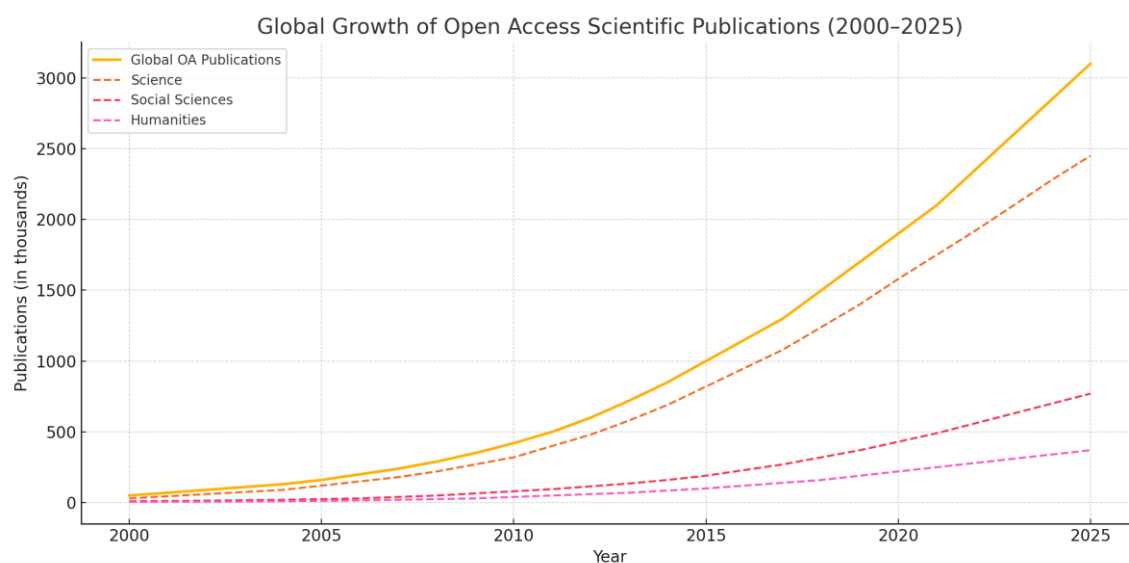
European Commission (2021). Open Science Monitor – Directorate-General for Research and Innovation.

Statista (2023). Number of science and engineering journal articles published worldwide from 2000 to 2021.

Dimensions.ai (2023). Global Research Trends: Open Access vs Non-OA Publications by Year.

Science Europe (2023). Monitoring Open Access and Open Science Policies Across Europe.

Figure 5: Global growth of Open Access scientific publications (2000–2025)



Sources:

UNESCO (2021). UNESCO Recommendation on Open Science. Paris: UNESCO Publishing.

European Commission (2021). Open Science Monitor – Directorate-General for Research and Innovation.

Piwowar, H., Priem, J., et al. (2018). The state of OA: a large-scale analysis of the prevalence and impact of Open Access articles. *PeerJ*, 6, e4375.

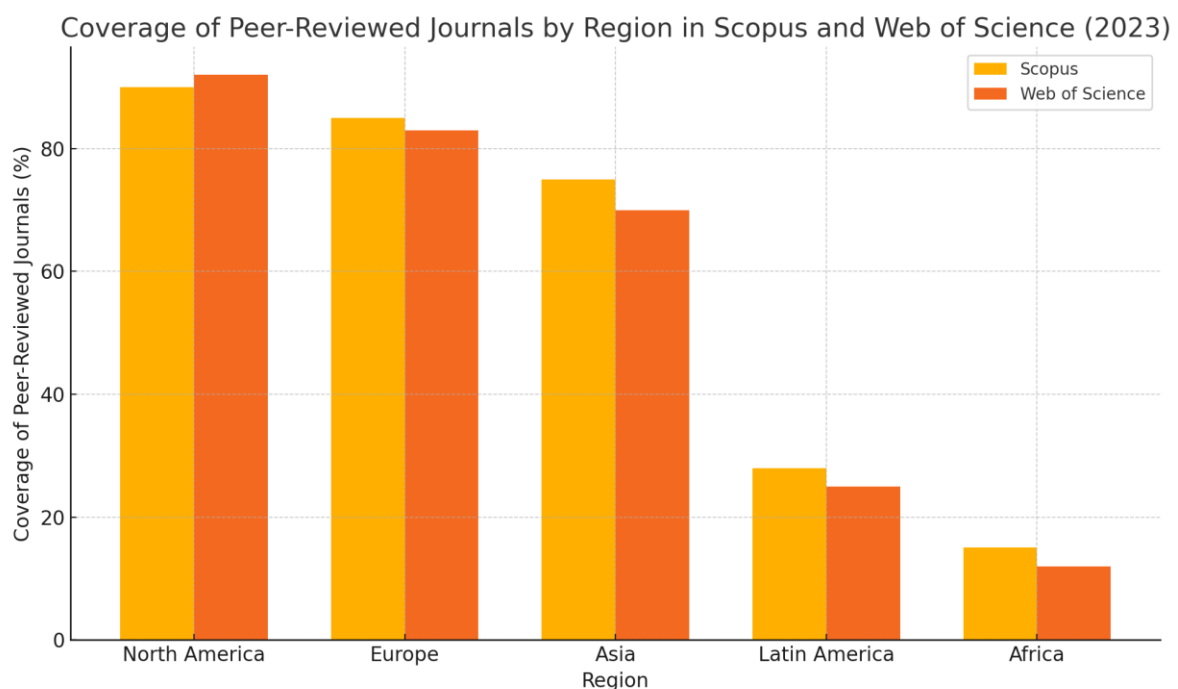
Science Europe (2023). Monitoring Open Access and Open Science Policies Across Europe.

Statista (2023). Share of scientific articles published in Open Access journals worldwide from 2009 to 2022.

Dimensions.ai Global Research Reports (2023). Trends in Open Access publishing by discipline.

Figure 6: Regional Coverage of Peer-Reviewed Journals in Scopus and Web of Science (2023)

This figure illustrates the asymmetrical indexation of peer-reviewed journals across major world regions. While North America and Europe show over 80% coverage in Scopus and Web of Science, Latin America and Africa remain significantly underrepresented, raising concerns over epistemic visibility and evaluative parity in global science



Sources: UNESCO Science Report (2021); Clarivate Analytics (2023); SCImago Journal Rank Database (2023).

Diamond OA represents a paradigmatic shift by decoupling publishing from commercial payment. Platforms do not charge authors or readers; they rely on public funding, institutional support, and consortial governance, reframing dissemination as a collective responsibility. SciELO and RedALyC (see 6.2) host 2,000+ multilingual, regionally grounded journals supported by public councils and inter-university collaborations, challenging epistemic centralisation. Their governance (academic committees and public agencies) contrasts with proprietary decisions in commercial firms. Yet exclusion from Scopus/Web of Science persists (Alperin et al., 2019). In India, Shodhganga and ShodhSindhu strengthen national repositories; in China, regulatory interventions and national science data platforms aim at infrastructural sovereignty. Constraints remain, underfunding, interoperability gaps, and marginalisation in performance regimes, limiting scalability.

Policy momentum is growing. Australia’s 2023 OA Policy Revision mandates embargo-free deposit and supports diamond OA pilots. UNESCO’s 2021 Recommendation (<https://unesdoc.unesco.org/ark:/48223/pf0000378841>) sets a global framework; EUA (2023) shows gaps: fewer than one in four institutions monitor article-level costs or align procurement with transformative criteria. Ultimately, Big Deals reflect entrenched practices shaped by reputational dependency, risk aversion, and weak public infrastructure. Overcoming dependency requires sustained investment, revised evaluation, and adoption of interoperable, sovereign platforms, as illustrated by Australia’s National Strategy (2023), Latin America’s RedALyC/SciELO, France’s HAL and Recherche Data Gouv, UC’s renegotiations with Elsevier, and Sweden’s Bibsam terminations.

6.4 Responses to the Open Access movement

Policy, infrastructural, and institutional responses increasingly aim not just to mitigate exclusion but to reconfigure scholarly communication. Plan S (2018) remains highly impactful: according to cOAlition S’s 2023 monitoring review, more than 75% of funded articles were published in fully open access venues or archived in compliant repositories (cOAlition S, 2023, <https://www.coalition-s.org/plan-s-monitoring-report-2023/>). Outside Europe, however, uptake is limited, and collaboration with agencies in underfunded regions or with humanities publishers remains inconsistent.

Rights Retention Strategies (RRS) allow deposit regardless of embargoes and have been adopted by institutions such as Harvard, MIT, Edinburgh, and ETH Zurich. France’s Décret n°2021-1572 guarantees the right to deposit publicly funded articles after a maximum six-month embargo. In Germany, the DEAL consortium has introduced a public APC monitoring dashboard (<https://deal-operations.de/analyse/open-access-monitor/>), though cost asymmetries persist.

Infrastructure plays a decisive role. France’s HAL now hosts more than 1.4 million full-text documents (developed by CNRS with 150+ partner institutions) and interoperates with EOSC. Canada’s FRDR enables bilingual data sharing. Australia’s 2023 National OA Strategy mandates zero-embargo deposit and funds diamond OA. In Latin America, networks such as AmeliCA and CLACSO provide multilingual, regionally sustained platforms (<https://www.amelica.org/>; <https://www.clacso.org.ar/>).

Community-driven infrastructures further expand bibliodiversity without commercial dependence. PKP’s Open Journal Systems (OJS) supports more than 30,000 journals (<https://pkp.sfu.ca/>). Platforms such as MediArXiv, AfricArXiv, and SciPost contribute to disciplinary and regional diversity, though they face precarious funding. Civic tools like the Open Access Button and the Open Access Tracking Project (OATP) improve discoverability and monitoring, and are increasingly integrated into institutional workflows (Harvard Open Access Project, 2024).

Capacity gaps, however, remain stark. UNESCO’s 2022–2023 workshops show that most low- and middle-income countries still lack national OA policies or robust infrastructures, relying instead on externally hosted repositories with limited preservation (UNESCO, 2022, <https://unesdoc.unesco.org/ark:/48223/pf0000378841>). Many institutions in underfunded regions and in underdeveloped countries are also absent from multilateral governance fora, limiting their influence in setting norms. Regional initiatives seek to respond: Africa’s AOSP

(<https://africanopenscience.org.za/>) coordinates policies, repositories, and training; the Latin American Science Council (COLAB, 2022) proposes horizontal coordination, shared metadata, and platform sovereignty.

Evaluation reform is equally pivotal. CoARA now brings together more than 600 institutions committed to reducing reliance on journal metrics and recognising broader scholarly contributions (<https://coara.eu/>). The Netherlands' "Recognition & Rewards" programme revises promotion criteria to include Open Science engagement. Without a realignment of incentives, OA risks reinforcing existing prestige hierarchies.

In sum, responses to OA mark a shift from rhetorical endorsement to pragmatic implementation. Yet reforms remain incomplete, fragmented, and vulnerable to rollback. Building a sustainable, plural OA ecosystem requires adoption and stable funding of tested policies and infrastructures: Australia's National OA Strategy (2023); France's Second National Plan for Open Science (2021–2024), with HAL, Recherche Data Gouv, and multilingual incentives; Latin America's AmeliCA and RedALyC consortia; and recognition reforms via CoARA and the Dutch framework (VSNU, NWO, KNAW). Convergence around such measures, beyond isolated national experiments, will be key to making OA structurally inclusive and sustainable.

7. Institutionalisation of Open Science

7.1 From grassroots advocacy to institutional commitment

The institutionalisation of Open Science in the second decade of the twenty-first century marked both a turning point and a source of tension within the broader movement reshaping knowledge production and dissemination. Its rise cannot be separated from earlier shifts: innovation-driven public policies, the dominance of performance metrics, and techno-economic logics influencing research priorities. Grassroots practices, preprint repositories like arXiv and bioRxiv, scholar-led journals, and non-profit initiatives such as PLOS, served as prototypes later formalised by institutions. Originating in resistance to commercial monopolies, these initiatives shaped the normative and technical foundations of Open Science. Their legacy, openness, participation, and critique, continues to inform current frameworks.

As Open Science gained recognition by governments, funders, and research organisations, its ethos of transparency, equity, and participation was continually renegotiated. Formalisation raises dilemmas : does it preserve transformative ambitions or domesticate them ? Can implementation frameworks include diverse epistemologies and research cultures, or do they risk reproducing asymmetries under the banner of openness? Recent assessments of national strategies highlight persistent gaps between commitments and provision for infrastructure, multilingual knowledge, and non-commercial dissemination channels (European Commission, 2023; Pontika et al., 2022).

Policy approaches illustrate these tensions. UNESCO's Recommendation on Open Science frames openness as a global public good, stressing equity, epistemic diversity, and multilingualism (UNESCO, 2021). By contrast, the OECD's principles on research data mobilise openness primarily for innovation and competitiveness, privileging market efficiency and public-private partnerships (OECD, 2021). The European Union attempts a hybrid path, embedding Open Science across Horizon Europe while operating within a publishing system still dominated by commercial actors. The competing logics, public good versus market control, global cooperation versus national strategies, reveal the ongoing struggle over the meaning of openness.

Mandates for open data and open access enhance transparency and reproducibility but may reinforce inequities when linked to costly article processing charges (APCs) or when compliance presumes robust institutional support. Reform of research evaluation, central to Open Science, remains contested, as journal-based indicators continue to shape recognition and funding despite initiatives such as DORA and the Leiden Manifesto (DORA, 2012; Hicks et al., 2015; Moher et al., 2020). Whether Open Science becomes a mechanism for collaboration and accessibility, or another layer of hierarchy, depends on how these tensions are resolved in practice.

7.2 Institutionalisation through international frameworks

The institutionalisation of Open Science has been shaped by different international frameworks. Intergovernmental organisations such as UNESCO, the OECD, and the European Union have each set out distinct agendas that mirror broader geopolitical, economic, and epistemological tensions.

- **UNESCO:** frames Open Science as a *global public good*. The 2021 Recommendation stresses equity, epistemic diversity, multilingualism, and South–South cooperation. Its weakness is that it is not legally binding, so countries can adopt it symbolically without making structural changes (UNESCO, 2021).
- **OECD:** presents Open Science as a *driver of innovation and growth*. Its guidelines on access to research data (OECD, 2007; updated 2021) prioritise efficiency, interoperability, and public–private collaboration, but often downplay issues of equity and epistemic diversity (OECD, 2021).
- **European Union:** adopts a *hybrid approach*. Initiatives such as Horizon Europe and Plan S combine elements of equity and competitiveness through conditional mandates. However, these can drive up APC costs and strengthen the position of large commercial publishers, while implementation remains uneven (European Commission, 2022).

Table 5 contrasts the orientations of UNESCO, the OECD, and the European Union, making their assumptions, governance models, and policy tools easier to compare:

Table 5: Orientations of UNESCO, the OECD, and the European Union

Organisation	Core Orientation	Key Instruments	Underlying Logic	Critiques
UNESCO	Open Science as a global public good	Recommendation on Open Science (2021)	Equity, epistemic diversity, multilingualism, South–South cooperation	Not binding; risks symbolic adoption without structural reform
OECD	Open Science as a driver of innovation and growth	Guidelines on Access to Research Data (2007, 2021)	Market efficiency; public–private partnerships	Reinforces commercial interests; neglects equity and diversity
European Union	Hybrid: equity and competitiveness	Horizon Europe; Plan S	Mixes UNESCO and OECD logics; conditional mandates	Increases APC costs; consolidates commercial publishers; uneven uptake

In addition, the International Science Council (ISC), which brings together over 200 academies, unions, and associations, plays a normative role. The ISC was closely involved in drafting UNESCO’s 2021 Recommendation and argues for publicly owned, community-driven infrastructures, multilingual dissemination, and reform of publishing. It acts as a counterweight to more technocratic or market-oriented models (International Science Council, 2020; 2021). Overall, governance of Open Science is geopolitically complex: while actors use the same

vocabulary of transparency, access, and participation, they pursue contrasting strategic priorities and reflect different power dynamics.

7.3 Comparative perspectives : global comparisons in Open Science

National trajectories reveal contrasts shaped by capacity, governance, and political economy. In the United States, NIH and NSF policies provide strong precedents, yet less than half of federally funded research is fully accessible; the absence of a national repository system produces inconsistent implementation, especially across smaller institutions (National Academies, 2022). China's state-led expansion, via platforms such as the National Science Data Center and ministerial mandates, has boosted visibility and output (SCImago, 2023), but concerns persist about data transparency and the balance between national priorities and international cooperation. Australia blends central policy direction with university autonomy: the Australian Research Data Commons (ARDC) supports FAIR-aligned sharing and training, while tensions remain around commercialisation in sectors such as agriculture and extractives. In Japan, platforms like J-STAGE and policies by the Japan Science and Technology Agency signal commitment, yet adoption outside top institutions remains gradual amid hierarchical academic norms. Russia's initiatives promote open access, but geopolitical isolation from major international collaborations limits integration.

Within Europe, integration of Open Science into doctoral education varies widely: 64% of universities in Northern and Western Europe include structured components, compared with 28% in Southern and Eastern Europe (EUA, 2023). These disparities, also visible in infrastructure, licensing practices, and data stewardship skills, indicate that adaptive, context-sensitive strategies are more effective than universal models.

7.4 Challenges and critiques of institutionalisation

Institutionalisation has brought legitimacy and scale to Open Science but has also exposed persistent inequalities. Well-funded universities in North America and Western Europe are often equipped to meet the infrastructural demands of openness, while institutions in Central Asia, parts of Eastern and Southern Europe, and many regions in Africa and Latin America face gaps in repositories, preservation, and high-speed connectivity; many rely on externally hosted platforms with limited long-term guarantees (UNESCO, 2023). APC-based models exacerbate exclusion for researchers lacking institutional support, shifting costs from readers to authors and their organisations (Bosman et al., 2021).

Evaluation systems remain fragmented and often symbolic. Despite endorsements of DORA and the Leiden Manifesto, many institutions still privilege journal impact factors and proxy metrics. A recent study found that over 65% of research organisations across OECD countries retain JIF-based criteria in promotion and tenure guidelines; in Germany, fewer than 30% of universities explicitly recognise Open Science contributions in promotion (DFG, 2022; Moher et al., 2022). In Spain and Italy, national assessments continue to reward publication in paywalled journals indexed in Scopus and Web of Science, limiting incentives for openness; surveys by CLACSO and LA Referencia similarly underscore the gap between rhetoric and evaluation practice (CLACSO, 2022; EUA, 2023, LA Referencia, 2021;).

Nevertheless, alternatives exist. Funding agencies such as FWF (Austria), SNSF (Switzerland), and DFG (Germany) finance infrastructures and, in transitional phases, APCs. In France, OpenEdition sustains non-commercial platforms for the humanities and social sciences; Norway's incentive-based schemes reward repositories, preprints, and data sharing. Regionally grounded platforms, the African Open Science Platform and LA Referencia, emphasise capacity-building, shared metadata, and public ownership over purely market models (Arza & van den Eynden, 2023). These initiatives demonstrate that inclusive, plural Open Science systems can be implemented when embedded in sustained, well-resourced public policy frameworks.

7.5 Bridging global divides: towards a coherent and inclusive framework for Open Science

Institutionalisation has scaled Open Science but also reinforced disparities in resources, infrastructure, and training. APCs expanded dissemination but introduced new exclusions (Arza & Van den Eynden, 2023; Suber, 2021). Integration of openness into academic evaluation remains limited: journal-based metrics persist despite DORA, CoARA, and reform programmes (CoARA, 2023; Hicks et al., 2015; Moher et al., 2018;). FAIR principles offer a shared foundation, but adoption is still partial across disciplines and regions.

Inclusive policies demonstrate alternatives. Norway's performance-based model links open dissemination to funding. Latin America's Redalyc–AmeliCA ecosystem provides multilingual, non-commercial publishing and scholar-led peer review. South Africa's National Research Foundation embeds Open Science into funding and training. France's Open Science Committee (CoSO) coordinates roadmaps such as Recherche Data Gouv and the Plan pour la science ouverte (2021–2024). These examples show Open Science can be sustainable when anchored in long-term public investment.

Global coordination advances through the OECD's 2021 Recommendation on access to research data, EOSC, and UNESCO's Global Open Science Cloud (2023). Their success depends on balancing global coherence with national diversity, interoperable standards, and investment in skills such as data stewardship. Transregional alliances, the G7 Open Science Working Group, AmeliCA, and the African Open Science Platform, illustrate reciprocity and capacity sharing. Key priorities include multilingual platforms, community-governed infrastructures, broader evaluation frameworks, and stable funding.

Adoption on paper does not always mean practice. Many national roadmaps cite UNESCO (2021) but follow OECD's economic framing, tying openness to industrial policy or university–industry partnerships (OECD, 2021). In the EU, Horizon Europe mandates data management and responsible metrics, but compliance often reduces to checklists (European Commission, 2022). cOAlition S accelerated immediate access but also spurred transformative agreements that consolidate publisher power and channel funds into APC-based workflows.

Epistemic justice remains a gap. UNESCO emphasises multilingualism, Indigenous knowledge, and South–South cooperation, yet these remain under-resourced (UNESCO, 2021). The International Science Council stresses community governance and non-commercial infrastructures as preconditions for inclusivity (International Science Council, 2020; 2021). Hence similar vocabularies yield divergent institutional designs: some focus on compliance, others on capacity-building and public ownership.

National contexts vary. In the U.S., agency mandates coexist with decentralised policies, creating a patchwork where elite universities host repositories while smaller colleges lack infrastructure (National Academies, 2022). China rapidly expands repositories but is shaped by data localisation rules and strategic priorities (SCImago, 2023). Australia's ARDC supports FAIR adoption and training, though commercial pressures threaten sustainability. Japan's reforms progress slowly due to academic hierarchies, while Russia faces restrictions on participation in infrastructures such as EOSC.

Europe also shows contrasts. The Netherlands and Nordic countries integrate Open Science into doctoral training and sector-level bargaining, supported by strong repository systems. Elsewhere, mandates exist without changes to promotion criteria, leaving practices unchanged (EUA, 2023). Excellence frameworks and rankings continue to favour journal prestige and anglophone publishing cultures, even as DORA is endorsed.

These conditions shape researchers' choices. For early career scholars, especially in SSH, APC-centred models and journal hierarchies create trade-offs between visibility, careers, and openness. By contrast, Latin America demonstrates a different pathway: Redalyc and AmeliCA reduce reliance on APCs, support multilingual dissemination, and value scholar-led peer review (Arza & Van den Eynden, 2023; CLACSO, 2022; LA Referencia, 2021). In Africa, the African Open Science Platform advances policy, metadata, and training to address capacity gaps (Bezuidenhout et al., 2023).

Evaluation reform is central. DORA, the Leiden Manifesto, and CoARA all call for reducing journal-based metrics, recognising diverse outputs, and adopting narrative assessment. Implementation remains slow: universities acknowledge these principles but retain legacy rules; funders pilot narrative CVs while panels still request journal quartiles (CoARA, 2023; Hicks et al., 2015; Moher et al., 2018). Without aligning hiring, tenure, and funding, reforms risk remaining peripheral.

Practical solutions link policy, infrastructure, and skills. Norway ties funding to open dissemination. France's CoSO couples roadmaps with repository investment and data steward training. South Africa's NRF embeds Open Science in grants and curricula. These cases show durable change occurs when openness is integrated into everyday routines.

Cross-border coordination will be decisive. The OECD's 2021 Recommendation promotes convergence on data access; EOSC develops interoperable services in Europe; UNESCO's Global Open Science Cloud (2023) proposes a federated model. To avoid centre-periphery dynamics, initiatives must ensure reciprocity through regional hubs, multilingual metadata, and fair licensing, while monitoring participation from low- and middle-income countries. Fora such as the G7 Working Group, AmeliCA, and the African Open Science Platform suggest governance models combining shared principles with local adaptation.

The direction of institutionalisation depends on the convergence of evaluation, funding, and infrastructure. Priorities include multilingual publishing platforms, community-governed repositories aligned with FAIR, open-source software and long-term preservation, and assessment systems valuing openness and societal contribution. When these align, Open Science becomes not just policy but structural reality, globally coherent yet locally responsive.

Accountability is crucial. Institutions and funders should publish indicators on openness, share of outputs deposited without embargo, proportion of datasets with FAIR metadata, uptake of open-source tools, and multilingual outputs, disaggregated by discipline and career stage. Panels should document how qualitative assessment replaces journal proxies in grant and tenure. At national and European levels, resources must support less resourced universities for repositories, identifiers, and training. Where transformative agreements persist, independent cost audits should prevent APC inflation and protect community-owned alternatives. Finally, researcher-centred support is essential: funding for data stewards and software engineers, protected time for curation, and micro-grants for diamond and scholar-led journals. These steps operationalise UNESCO and ISC commitments. With steady public investment and reciprocity, they create conditions for institutionalisation to strengthen rather than weaken the democratic promise of Open Science.

8. Public and private research in the era of Open Science

8.1 Balancing innovation and public accountability

Public–private partnerships (PPPs) have become increasingly prominent in shaping Europe’s research and innovation landscape, while reflecting broader global trends. In the United States, commercialisation is channelled through agencies such as DARPA and BARDA, where federally funded research is closely tied to patenting and technology transfer (Sampat & Lichtenberg, 2011; Wagner, 2008). In China, state-coordinated models align industrial policy with strategic science through large mission-oriented consortia in biomedicine and green technologies (Liu & White, 2001; OECD, 2023). PPPs are often framed as tools to address grand societal challenges, bridging public interest and private innovation. Yet their role in Open Science remains contested.

On one side, PPPs mobilise capital, infrastructure, and expertise beyond the reach of many public institutions. The Innovative Medicines Initiative (IMI), a joint undertaking between the European Commission and EFPIA, is often cited as a model of collaboration. During COVID-19, PPP frameworks channelled resources toward diagnostics, treatments, and vaccines. On the other, critics highlight opaque data-access and exclusive licensing that restrict publicly co-funded outputs (Bertier et al., 2022; Rumsfeld & Scholten, 2023). Health and pharmaceutical research crystallise this paradox: public trust demands transparency, while commercial logics favour secrecy.

IMI2’s EBOVAC Ebola vaccine project illustrates this tension: although publicly co-funded, clinical data access and licensing terms remained unclear (Guston, 2020; European Parliament, 2021). Similar asymmetries appear across European PPPs, where large corporations dominate intellectual property (IP), data governance, and exploitation rights. The BioMed Alliance (2021) reported that academic partners in IMI projects had little influence over IP or data-sharing. In Clean Sky 2, Science|Business (2022) described how research institutions were sidelined in dissemination, while Airbus, Safran, and Leonardo controlled publication conditions. Clean Sky and Fuel Cells and Hydrogen Joint Undertakings advanced green innovation but faced scrutiny for restrictive data policies and corporate steering of priorities (EC JRC, 2022).

Universities and public research organisations often remain structurally disadvantaged in PPPs. Evaluations of Horizon Europe partnerships show universities frequently acting as subcontractors rather than equal partners, limiting influence over knowledge-sharing and engagement (EUA, 2023). In Europe’s Rail, university partners had little say in data-sharing design or steering committees, while Siemens and Alstom controlled publication timing on safety and performance (Science|Business, 2023). Safeguards such as data management plans, open-access clauses, and FAIR principles exist but are diluted in negotiations, with wide “commercial sensitivity” exemptions. A SPARC Europe/Science Europe review found more than 60% of EU-funded PPPs used restrictive or ambiguous frameworks (SPARC Europe, 2023).

Beyond Europe, PPPs shape research trajectories elsewhere. In the US, the Bayh–Dole Act entrenched the principle that public research should be rapidly commercialised, fostering tight university–industry links. In

Japan, METI-backed partnerships in robotics and automotive sectors have supported industrial leadership but attracted similar critiques of secrecy (OECD, 2021). In Brazil and South Africa, PPPs targeted agriculture and infectious disease, but unequal bargaining power often left public actors in subordinate roles (UNESCO, 2021). These cases underscore the structural dilemma: PPPs can accelerate translation, but without binding safeguards they steer public research toward private enclosures.

In sum, PPPs can scale innovation but, without enforceable openness, risk enclosing knowledge: public resources feed proprietary pipelines, accountability diminishes, and Open Science is reduced to compliance checklists rather than substantive transparency and equitable reuse.

8.2 Sectoral models and scaling challenges

Some PPP designs attempt to reconcile innovation with accountability. The Innovative Medicines Initiative (IMI), launched in 2008 as a joint undertaking between the European Commission and the European Federation of Pharmaceutical Industries and Associations (EFPIA) to accelerate medicines development and foster pre-competitive collaboration, emphasised such spaces to limit immediate proprietary claims and created multi-stakeholder governance with commitments to accessibility (European Commission, 2021). Yet independent analyses by Corporate Europe Observatory and Health Action International show that private stakeholders retained agenda-setting power, steering calls and evaluation criteria toward commercially profitable areas while neglecting low-return public health needs (Ozieranski & King, 2021). Moreover, interoperability standards and data protocols often mirror corporate preferences, limiting reuse, especially in low-resource contexts.

The Australian Research Data Commons (ARDC) provides another case. By coordinating universities, government, and private partners, it operationalises FAIR (Findable, Accessible, Interoperable, Reusable) principles at national scale and has improved data coordination and training. Yet sustainability concerns persist: funding cycles are short, critical services depend on private cloud providers, and risks of data commercialisation remain. OECD (2021) identifies this broader pattern: infrastructural openness frequently coexists uneasily with market-driven assetisation.

Artificial intelligence (AI) highlights these dilemmas. Algorithmic bias, data asymmetries, and black-box decision-making have prompted calls from AI Now Institute, AlgorithmWatch, and the Eticas Foundation for enforceable safeguards rather than voluntary ethics codes (Bender et al., 2021). Controversies, from welfare fraud detection in the Netherlands to predictive policing in the US, show how private actors in public projects deploy opaque and discriminatory systems. Non-disclosure agreements (NDAs) and trade secrets often block independent auditing and democratic oversight.

Geographic and institutional disparities complicate replication of “good” models. In underfunded contexts, public institutions risk becoming passive partners or data-extraction sites for global markets. UNESCO (2021) stresses that without reciprocal investment, technology transfer, and local governance, PPPs perpetuate rather than reduce inequities. Several African and South Asian projects demonstrate how infrastructures built under PPPs are managed abroad, with little local capacity-building.

The policy shift from post-war state-funded basic research to market-oriented frameworks, exemplified by the Bayh–Dole Act (1980), normalised university–industry partnerships and reframed knowledge as an economic asset (Mowery et al., 2004). For some, Open Science could renew science’s public mission (Dacos, 2020; UNESCO, 2021). For others, it risks absorption into proprietary regimes and competitive funding logics (Boukacem-Zeghmouri, 2021; Mirowski, 2018;). Publishers have also repositioned as analytics providers, combining APC-based journals with proprietary platforms that marginalise less-resourced scholars (Larivière et al., 2015). Selective openness, where firms exploit public research while restricting access to datasets, further entrenches asymmetries (Birkinshaw & Cohen, 2022).

Alternatives exist but remain fragile. AmeliCA and the African Open Science Platform (AOSP) aim to reduce reliance on commercial publishers and foster equitable knowledge-sharing (Chan et al., 2023). These models promote multilingualism, community governance, and diamond Open Access, yet face scaling challenges given the dominance of established actors and insufficient public investment. A transformative Open Science agenda requires sustained public funding for open infrastructures, robust support for scholar-led publishing, APC waivers for disadvantaged institutions, and PPP governance anchored in enforceable safeguards, equitable representation, transparent contracting, and redistributive commitments (Tennant et al., 2023).

8.3 Open Science in higher education: institutional contradictions, entrepreneurial agendas, and structural inequalities

Building on these structural tensions, the higher education sector offers a clear view of how they play out institutionally. Over the past two decades, universities have shifted toward an entrepreneurial, innovation-driven model (Ruano-Borbalan, 2018; 2022). This reframes them as engines of economic competitiveness, embedding Open Science within regimes that prioritise IP valorisation, technology transfer, and market-oriented partnerships. In this context, the rhetoric of openness is increasingly coupled with “impact,” “excellence,” and “commercialisation,” blurring boundaries between public mission and private return.

While Open Science is promoted as a way to democratise access, accelerate innovation, and foster public engagement, implementation is filtered through persistent inequalities, economic, infrastructural, linguistic, and epistemic, that distort its ambitions. Many earlier-identified issues, commercial capture, capacity asymmetries, selective openness, reappear in how universities govern “open” initiatives. Wealthier institutions, consortia, and multinational firms often define technical and normative standards, from repository architectures and metadata schemas to interoperability protocols, shaping not just access but also the terms of participation. As Mirowski (2018) notes, this produces a “neoliberal ideal” of openness, reinforcing dependence on privately owned platforms and metrics while reducing public influence over research priorities.

Institutional contradictions deepen this paradox. Universities may endorse Open Science mandates, yet still reinforce proprietary publishing models, outsource infrastructure to commercial vendors, and maintain evaluation systems dominated by journal impact factors and citation counts. The entrepreneurial turn aligns policies with technology parks, spin-offs, and incubators, selectively opening research only when competitive

advantage is preserved. Fecher & Friesike (2014) describe this as a clash between the democratising school of Open Science and reputational or pragmatic schools prioritising efficiency, branding, and commercial scalability.

These tensions are evident in the rise of MOOCs and so-called “open universities.” Platforms like FutureLearn, OpenClassrooms, and edX market themselves as democratising access through free or low-cost courses and alternative credential. Yet their governance is largely private or hybrid, dominated by corporate partners. Business models rely on monetising user data, premium services, and certification fees, embedding commercial imperatives in the very design of openness. Centralised production pipelines privilege dominant languages and Western pedagogical models, limiting local adaptation and reinforcing cultural and epistemic asymmetries.

Financial disparities exacerbate these divides. APC-based open access imposes heavy costs on underfunded researchers and universities, particularly in low- and middle-income countries and among early career scholars (Khoo, 2023; Piron et al., 2021). Waiver schemes are inconsistently applied, opaque, and burdensome. Thus, while readership expands, participation in the supposedly open corpus is stratified along economic lines.

Infrastructure inequality compounds these issues. High-performance computing, secure cloud storage, advanced labs, and persistent identifiers are vital for data-intensive fields like genomics, AI, and climate modelling, yet remain concentrated in elite institutions. Under-resourced partners, especially in the Global South, risk seeing their datasets extracted for disproportionate benefit elsewhere (Albornoz et al., 2022; Bezuidenhout et al., 2022).

Regional and community-driven initiatives seek to counter these dynamics. AmeliCA in Latin America and the African Open Science Platform (AOSP) promote nonprofit, multilingual, diamond OA infrastructures rooted in equity and epistemic plurality (Chan et al., 2023). These platforms enable open peer review, free dissemination, and governance by scholarly communities rather than corporate boards. Yet they face chronic underfunding, interoperability challenges, and difficulty securing political backing in a landscape shaped by platform capitalism and entrepreneurial universities.

If such contradictions persist, Open Science risks hollowing out its own normative foundations. Realising its inclusive potential requires sustained public investment in open-source infrastructures, systemic reforms to decouple communication from APC models, capacity-building tailored to underrepresented institutions and languages, and governance frameworks embedding transparency, equity, and participation (Tennant et al., 2023).

8.4 Structural tensions in the public–private nexus

The public–private interface in research and innovation has long been marked by both synergy and imbalance. Across sectors, a recurrent pattern appears: public institutions and publicly funded consortia generate foundational research, through taxpayer-funded laboratories, universities, and international programmes, while private corporations consolidate ownership of the most commercially valuable results. This asymmetry raises fundamental questions about the distribution of value, allocation of risks, and concentration of decision-making in contemporary knowledge economies (Mirowski, 2018; OECD, 2024).

The pharmaceutical sector illustrates this dynamic starkly. Breakthrough therapies often emerge from publicly funded biomedical research, yet their commercialisation is governed by exclusive patents and pricing that restrict access, particularly in low- and middle-income regions (Angell, 2005; 't Hoen, 2023). Disputes over COVID-19 mRNA vaccine patents and the WTO's limited TRIPS Waiver (2022) exposed how IP frameworks can override global health imperatives despite massive public investment (Hughes et al., 2023).

Similar patterns appear in artificial intelligence. Initiatives initially framed as open and mission-driven, such as OpenAI, have shifted to profit-maximising strategies, forming exclusive partnerships and restricting access to advanced tools and datasets (Heaven, 2023; Villum Research Programme, 2024). Concentrated computational resources, proprietary data, and elite expertise echo the concentration of vaccine manufacturing capacity during the pandemic, underscoring a cross-sector problem of access and control (UNESCO, 2023).

Green technologies reveal comparable imbalances. Innovations in solar energy, hydrogen fuel cells, and advanced batteries, often incubated in publicly funded EU programmes, are increasingly enclosed within corporate IP regimes. The rapid patenting of perovskite solar cells, built on years of EU-funded research, raises questions about whether the public will benefit proportionately (IRENA, 2024; Mathews & Tan, 2015). Although perovskites promise efficient, low-cost, flexible photovoltaics, concentration of IP in corporate hands restricts wider deployment, particularly in resource-constrained settings.

The COVID-19 pandemic highlighted these dynamics across fields. Public resources mobilised at unprecedented scale delivered vaccines, diagnostics, and therapeutics, yet these were quickly integrated into proprietary value chains (Callaway, 2021; WHO, 2023). The global scramble for vaccine access, and parallel struggles over AI datasets and clean energy patents, show how IP regimes and concentrated capacity can trump societal imperatives even when science is publicly funded (Chan et al., 2020; European Commission, 2023).

Attempts to redress imbalances, compulsory licensing in health emergencies, conditionality in public funding, or expanded public ownership of infrastructures, have faced strong resistance from industry (Baker, 2023). Corporations benefit not only from outputs of public research but also from the legitimacy it confers, reinforcing appropriation over collective benefit.

These tensions carry epistemic as well as economic consequences. In pharmaceuticals, restrictive patents delay generics, raise costs, and constrain public health interventions ('t Hoen, 2023). In AI, proprietary control of datasets, compute, and algorithms hampers replication and peer review, undermining transparency (Bender et al., 2021; UNESCO, 2023). In sustainability sectors, proprietary barriers risk slowing diffusion of critical technologies to the regions most vulnerable to climate change (IRENA, 2024).

Addressing these challenges requires redistributive policy frameworks. Greater direct public funding can reduce reliance on corporate agendas, aligning priorities with public interest (OECD, 2024). Enforceable open-access and open-data provisions in technology transfer agreements can ensure that publicly funded outputs remain broadly available. Differential pricing models, adapted from pharmaceutical access programmes, could extend to scientific infrastructures and data services, enhancing participation by under-resourced institutions. Tailoring

Open Science initiatives to regional capacities rather than imposing uniform standards can foster meaningful engagement (UNESCO, 2023).

Governance reform is also critical. PPPs can mobilise resources and expertise, but without strong governance they exacerbate disparities (Marin Dacos, 2024). Transparent frameworks should mandate accountability, disclosure of contractual terms, and safeguards against conflicts of interest. Pre-competitive collaboration in high-cost, high-risk sectors such as pharmaceuticals and renewable energy can reduce IP disputes and promote joint problem-solving (European Commission, 2023). Public institutions should retain strategic oversight of research agendas, embedding inclusivity, transparency, and ethics in agreements (Hao, 2020). At the same time, capacity-building is essential to enable less wealthy institutions to participate fully rather than remain peripheral (UNESCO, 2023).

8.5 Intellectual property and access to knowledge

A central tension in public–private research collaborations is control over intellectual property (IP), which determines how knowledge is accessed, shared, and commercialised. While public funding supports early-stage research, private companies often claim patents on subsequent innovations, limiting accessibility and raising ethical concerns about the privatisation of publicly funded discoveries. This creates an uneven research landscape, where the interests of governments, academic institutions, corporations, and civil society frequently clash.

A key debate centres on whether scientific knowledge, especially when developed with public funds, should be treated as a global public good or remain subject to commercial exploitation. Some argue that stringent IP protections incentivise private sector investments in innovation (Mazzucato, 2018), while others contend that excessive privatisation stifles scientific progress, increases costs, and deepens inequalities in access to technology (Stiglitz, 2006).

In the semiconductor industry for example, many foundational breakthroughs in materials science and manufacturing were enabled by public funding, yet rapid patenting by major firms created barriers for smaller companies and developing nations (Breznitz, 2021). In artificial intelligence, major advances in machine learning and natural language processing benefited from public research grants, but companies have since commercialised these outcomes, restricting access to proprietary models and datasets (Heaven, 2023). In biotechnology, the development of CRISPR-Cas9 sparked intense disputes over IP rights as companies obtained patents for various applications, raising concerns about accessibility and licensing constraints (Doudna & Charpentier, 2020). In the renewable energy sector, publicly financed advances in photovoltaic materials and battery storage faced patent wars that complicated diffusion and slowed adoption (Mathews & Tan, 2015).

These cases have reignited calls for a reassessment of global IP frameworks, including proposals for compulsory licensing and technology transfer mechanisms, such as those championed by the European Union and discussed within WIPO. However, large technology and pharmaceutical companies, as well as wealthy nations, have resisted such initiatives, citing concerns about disincentivising future R&D (Gopakumar, 2022). This ongoing

tension underscores the need for balanced policies that align scientific progress with equitable access to critical innovations.

8.6 Reclaiming equity and the future of collaboration

The public–private interface in research and innovation has long been marked by both synergy and imbalance. Across sectors, a recurrent pattern emerges: public institutions generate foundational research, through taxpayer-funded laboratories, universities, and international programmes, while private corporations consolidate ownership of the most commercially valuable outcomes. This asymmetry raises fundamental questions about value distribution, risk allocation, and decision-making in contemporary knowledge economies (Mirowski, 2018; OECD, 2024).

The pharmaceutical sector illustrates this dynamic. Breakthrough therapies often originate in publicly funded biomedical research, yet their commercialisation is governed by exclusive patents and pricing that restrict access, especially in low- and middle-income regions (Angell, 2005; 't Hoen, 2023). Disputes over COVID-19 mRNA vaccine patents and the WTO's limited TRIPS Waiver (2022) exposed how IP frameworks can override global health imperatives despite massive public investment (Hughes et al., 2023).

Artificial intelligence shows similar trends. Initiatives initially framed as open, such as OpenAI, shifted to profit-maximising strategies, forging exclusive partnerships and restricting access to advanced tools and datasets (Heaven, 2023; Villum Research Programme, 2024). Concentrated computational resources and proprietary data mirror the vaccine manufacturing bottlenecks of the pandemic, underscoring a cross-sectoral problem of access and control (UNESCO, 2023).

Green technologies reveal comparable imbalances. Innovations in solar energy, hydrogen fuel cells, and advanced batteries, often incubated in EU programmes, are increasingly enclosed within corporate IP regimes. The rapid patenting of perovskite solar cells, based on years of publicly funded research, raises questions about whether the public will see proportional benefits (IRENA, 2024; Mathews & Tan, 2015). Although perovskites promise efficient, low-cost photovoltaics, IP concentration restricts deployment, particularly in resource-constrained settings.

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Addressing these challenges requires redistributive policies and governance reform. Greater direct public funding can reduce reliance on corporate agendas, aligning priorities with public interest (OECD, 2024). Enforceable open-access and open-data provisions in technology transfer agreements can ensure publicly funded outputs remain accessible. Differential pricing models, adapted from pharmaceutical programmes, could extend to infrastructures and data services, supporting under-resourced institutions. Tailoring Open Science initiatives to regional capacities fosters meaningful engagement (UNESCO, 2023).

Robust governance is essential. PPPs can mobilise resources and expertise, but without safeguards they exacerbate disparities (Marin Dacos, 2024). Transparent frameworks should mandate accountability, disclosure of contracts, and conflict-of-interest safeguards. Pre-competitive collaboration in high-cost, high-risk sectors can reduce disputes and promote joint problem-solving (European Commission, 2023). Public institutions must retain strategic oversight of research agendas, embedding inclusivity, transparency, and ethics in agreements (Hao, 2020). Capacity-building is equally vital to enable less wealthy institutions to participate fully rather than remain peripheral (UNESCO, 2023). In this way, the public-private nexus can strengthen rather than undermine the democratic promise of Open Science.

9. Political and geopolitical dimensions of Open Science

9.1 Open Science, democracy, and the politics of openness

Open Science is frequently portrayed in scholarship and international policy as aligned with liberal democratic values, emphasising transparency, equity, and inclusivity. Yet this portrayal requires nuance: tensions persist between these ideals and the political, institutional, and cultural contexts in which Open Science is enacted. Fecher & Friesike's (2014) mapping of Open Science "schools" highlights this duality: the "democratic" and "public" strands promote citizen engagement and access to knowledge, shaping academic and policy discourse, but they have been critiqued for idealism, neglect of structural inequalities, and limited attention to geopolitical dimensions of governance.

The UNESCO (2021) Recommendation similarly presents openness as a path to human rights and democratic participation, but implementation has been uneven, raising doubts about its effectiveness in addressing disparities. Levin et al. (2022) show that while governments invoke democratic ideals and citizen participation, these commitments often coexist with economic competitiveness and strategic interests, creating tensions between rhetoric and practice.

This framing draws on a broader intellectual lineage. Dewey saw inquiry as integral to democracy; Kitcher (2001) envisioned "well-ordered science" shaped by public deliberation. Building on this, Jasanoff (2005) and Jasanoff & Simmet (2017) argue that open inquiry can strengthen civic epistemologies when institutions redistribute authority and empower diverse publics. More recently, Brown, Guston & Sarewitz (2021) and Stilgoe (2022) confirm that without supportive governance, openness rarely ensures equitable participation.

As discussed in Chapters 4, 6, and 7, the science–democracy relationship is historically contingent and politically contested. Scientific institutions have long served state power and elite reproduction (Ezrahi, 1990; Pestre, 2003). Today, AI illustrates these dynamics: the EU's AI Act combines ethical safeguards with sovereignty claims (European Commission, 2023); China's AI Development Plan directs vast public investment under strict state control (Zeng et al., 2022); and the U.S. National AI Initiative Act, reinforced under Trump's 2025 administration, tied AI funding to techno-nationalist agendas.

Openness can also be extractive. Well-documented cases of so-called biopiracy, such as the neem tree (used in Indian medicine for centuries, patented by W.R. Grace and the U.S. Department of Agriculture in 1994), turmeric (a patent granted in 1995 by the U.S. Patent Office on its wound-healing properties, later revoked after a legal challenge by India's Council of Scientific and Industrial Research), and hoodia (a plant traditionally used by the San people of Southern Africa to suppress appetite, patented by South Africa's CSIR in 1997 and later licensed to pharmaceutical companies), illustrate how intellectual property regimes have allowed corporations to appropriate Indigenous and local knowledge under the guise of open scientific or trade frameworks (Shiva, 2001; Wynberg, 2004). Even established democracies, facing democratic backsliding (Freedom House, 2024; V-Dem, 2024), often maintain technocratic, centralised science policy that sidelines social sciences and humanities (Bauer et al., 2023; Felt, 2017; Nowotny, 2003; OECD, 2023). Citizen science and open data portals broaden access but, without power-sharing, risk becoming symbolic gestures.

Transparency, a celebrated principle of both democracy and Open Science (Fung et al., 2007; Heald, 2006; Peixoto & Fox, 2016), is not inherently democratising. Disclosure without participatory frameworks rarely shifts power relations (Bovens, 2007; Wessler et al., 2021). The CORD-19 initiative during COVID-19 showed the potential for rapid knowledge sharing (Andersson & Becker, 2022) but also the risks of unreviewed data fuelling confusion (Ioannidis, 2022). Without interpretive infrastructure, transparency can reinforce hierarchies, serve managerial control, or destabilise consensus (Birchall, 2011; Flyverbom, 2019).

Inclusivity and equity, central to UNESCO's Recommendation (2021), remain largely aspirational. Initiatives like the European Open Science Cloud require capacities unevenly distributed worldwide (Darch & Hrynaskiewicz, 2021; Hansen et al., 2023; Leonelli, 2020). Citizen science often restricts participation to data collection (Leclerc & Dupont, 2023; Williams et al., 2023), offering little influence over design or policy, thereby reinforcing hierarchies (Rowe & Frewer, 2004).

The gap between Open Science's democratic ideals and operational realities remains wide. Realising its potential requires embedding openness in governance systems that tackle structural inequalities, provide interpretive frameworks, and enable genuine co-production of knowledge. Without such reforms, grounded in insights from political sociology, STS, and comparative politics, Open Science risks remaining an aspirational promise rather than a transformative force.

9.2 Geopolitical constraints and rivalries

Open Science is often presented as a borderless, inclusive, and collaborative global research ecosystem. Yet its implementation reveals entrenched geopolitical, economic, and institutional asymmetries. As highlighted in Chapter 4 (structural inequalities in infrastructure), Chapter 6.2 (research capacity and funding disparities), and Chapter 7.1 (unequal access to scientific networks), openness frequently serves national interests, reinforcing hierarchies rather than dismantling them (International Science Council, 2022; OECD, 2023; UNESCO, 2021).

This tension is longstanding. From Cold War-era space and nuclear rivalries to today's competition in AI, quantum computing, and biomedicine, science has functioned both as cooperation and strategic leverage. The COVID-19 vaccine race made this duality visible: unprecedented collaboration in data sharing and trials coexisted with restrictive export controls, proprietary mRNA patents, and unequal distribution shaped by advance purchase agreements (Smith & Patel, 2023; WHO, 2022). Similar dynamics appear in climate science, where access to high-resolution satellite data and models is uneven (WMO, 2023; Zhou et al., 2022), and in national quantum strategies, where classification and export controls restrict diffusion (European Commission, 2023; National Science and Technology Council, 2022).

The United States exemplifies how national science policy blends public investment with IP protections and security measures. The 2022 CHIPS and Science Act, 2023 semiconductor export controls, and 2024 NSF restrictions on AI collaborations reflect this trajectory (NSF, 2024; U.S. Department of Commerce, 2023). Scholars warn such policies risk fragmenting global networks (Jaffe & Jones, 2023; Lee & Chen, 2024). China pursues selective openness, pairing heavy investment in OA publishing and data platforms with data sovereignty laws like the 2021 Personal Information Protection Law (Liu & Li, 2023; Zeng et al., 2022). Russia, isolated since

its 2022 invasion of Ukraine, has pivoted to BRICS partnerships while sustaining initiatives such as CyberLeninka under state-aligned agendas.

The EU positions itself as a normative leader through Horizon Europe and EOSC, aiming to combine ethics and regulation (European Commission, 2023; Mazzucato, 2018). Yet internal asymmetries persist: wealthier states dominate infrastructure while others lag. Reliance on U.S. cloud services spurred GAIA-X to bolster sovereignty, but governance and interoperability challenges have slowed progress (European Court of Auditors, 2023; Gaia-X Association, 2024). Emerging powers follow diverse trajectories: India's Shodhganga and National Digital Library broaden access but with uneven uptake (Patra & Mishra, 2022); Brazil's SciELO has boosted visibility yet remains vulnerable to political shifts (Packer et al., 2021); and South Africa's role in the SKA telescope illustrates both promise and fragility of large-scale partnerships (Swinbank, 2022).

These cases show that Open Science evolves on a fragmented landscape shaped by strategic imperatives and resource gaps. Data localisation laws, dual-use export controls, and weak enforcement of global frameworks like UNESCO's Recommendation (2021) constrain reciprocity. Moving beyond rhetoric requires embedding enforceability and equity: UNESCO's Open Science Partnership could include binding commitments on equitable data sharing; regional platforms such as the African Open Science Platform and AmeliCA could be co-financed and capacity-focused (Chan et al., 2024; UNESCO, 2023). Anchoring openness in climate diplomacy, trade, and international standards-setting (ISO, ISC) would reinforce its integration into governance.

Multilateral fora, the G20 Research Ministers' Meetings, OECD Global Science Forum, and the Global Research Council, should back these principles with pooled funding, regional hubs, enforceable cross-border agreements, and inclusive governance for low- and middle-income countries. Precedents exist: the Belmont Forum's transnational co-funding and Horizon Europe's Widening Participation schemes. Without such commitments, Open Science risks remaining dominated by powerful blocs. As concluded in Chapter 7.3 and synthesised in Chapter 8.5, making openness a structural reality requires embedding it in monitored, well-resourced, and sanction-backed frameworks with mechanisms for accountability and equitable capacity building.

9.3 A fragmented global landscape

The global architecture of Open Science today is less the product of coordinated strategy than of overlapping tensions between competing political models, economic regimes, and epistemic cultures. As shown throughout this report, in Chapters 1 (historical genealogies), 3.6 (critical perspectives), 6.4 (institutionalisation challenges), and 7.2–7.3 (public–private and regional asymmetries), Open Science operates within unresolved structural contradictions. Rather than converging on a universal framework, it has become an arena where openness and protectionism, public goods and proprietary knowledge, institutional incentives and epistemic justice are continually negotiated. These tensions echo decades of asymmetries in science diplomacy, infrastructure, and epistemic authority. While UNESCO articulates visions of shared openness, implementation is shaped by regional political and material conditions, resulting in a fragmented landscape.

One axis of fragmentation concerns disparities in scientific infrastructure and digital capacity. Many institutions in Africa, Southeast Asia, and parts of Latin America still lack high-speed internet, data repositories, or

computational facilities needed for data-intensive science. Even when data is “open,” the ability to process and repurpose it remains concentrated in well-resourced institutions, mostly in North America and Western Europe. UNESCO’s 2023 monitoring report notes that only 43% of low-income countries have national policies supporting open data infrastructures, compared to more than 85% of high-income countries.

Institutional fragmentation deepens these gaps. Regional frameworks such as the European Open Science Cloud (EOSC), AmeliCA, and the African Open Science Platform provide shared visions, but uptake and sustainability vary. EOSC participation remains uneven, with lower-resourced EU members constrained by capacity. AmeliCA offers a nonprofit alternative in Latin America but faces limits in scaling beyond the region. The result is a layered architecture that mirrors the stratified access to platforms, infrastructures, and funding examined in Chapters 6 and 7.

National regulations also diverge. Governments like the U.S. and China treat research data as a matter of national security or economic competitiveness, adopting localisation laws, export controls, and dual-use restrictions. Even in democratic contexts, decentralised frameworks create inconsistent mandates: in the U.S., policies differ across agencies and institutions. These regulatory asymmetries block shared global standards and sustain fragmentation.

Commercialisation compounds the problem. Transnational publishers and infrastructure providers operate across borders but align with national jurisdictions and profit motives. Transformative agreements expand open access yet reinforce the dominance of large publishers and divert funds from alternatives. As noted in Chapter 6, initiatives like Plan S tried to realign incentives but remain Eurocentric and face resistance elsewhere.

Efforts to bridge fragmentation, such as the Research Data Alliance and the International Science Council, promote interoperability and inclusivity but lack enforcement. UNESCO’s monitoring framework offers benchmarks yet relies on voluntary reporting. Addressing these gaps requires political will, equitable investment, and shared governance, not just technical standards.

Promising directions include transregional alliances and inclusive infrastructures. The G7 Open Science Working Group has proposed shared principles for data governance, while initiatives like India’s South–South collaborations or Africa’s Science Granting Councils Initiative foreground regional needs. These models suggest how multilateral engagement can combine local capacities with global frameworks.

Ultimately, as noted in earlier discussions on geopolitics (Chapter 8.2) and institutional asymmetries (Chapter 6.4), fragmentation reflects broader governance tensions: cooperation versus sovereignty, inclusivity versus competitiveness, openness versus control. Open Science cannot follow a one-size-fits-all model; it must evolve as a plural, context-sensitive process. Future policy must emphasise not only openness but also epistemic justice, ensuring that all regions and communities can both contribute to and benefit from scientific knowledge on equitable terms.

10. Engaging society in research

10.1 Citizen Science as a bridge between public participation and open knowledge

Citizen science, defined as the active participation of non-professional volunteers in generating, analysing, and disseminating scientific knowledge, has evolved from a peripheral outreach activity into a recognised mode of research that challenges traditional structures of authority, legitimacy, and knowledge creation. Its roots go back to Enlightenment amateur naturalists, 19th-century workers' scientific societies (Brownstein et al., 2008; Callon et al., 2001), and the activism of the 1960s (Haklay, 2013). In its modern form, the rise of digital platforms in the early 2000s, such as iNaturalist, OpenStreetMap, and Zooniverse, expanded participation at scale, making citizen science both more visible and more complex. As highlighted in Chapter 3 on digital infrastructures and Chapter 7 on institutionalisation, citizen science is now central not only for expanding participation but also for addressing systemic inequalities, reshaping epistemic boundaries, and influencing governance.

The complexity of citizen science lies in its dual potential. Central to current debates is the relationship between citizen science, Open Science, and Open Access: can it genuinely democratise knowledge production, or does it risk reinforcing institutional or market-driven control? Science and Technology Studies (STS) perspectives, particularly co-production and reflexive governance, frame citizen science as a site where boundaries between expert and lay knowledge are renegotiated. Hecker et al. (2018) examine its governance and policy impacts, while Eitzel et al. (2017) emphasise epistemic diversity, arguing that open access must encompass diverse ways of knowing, not just technical data availability. This positions citizen science as a test case for whether openness functions as a social practice rather than merely a technical standard.

As Chapters 6 and 8 note, the institutionalisation of openness is constrained by unequal infrastructures and persistent asymmetries. Citizen science can therefore either contest or reproduce hierarchies. Bocquet's (2022) study of French biodiversity monitoring shows how citizen contributions can be absorbed into top-down systems without shared decision-making. In Latin America, Rodríguez et al. (2021) document how community-generated data was sometimes extracted without reciprocal benefits, revealing how Open Science rhetoric may conceal exploitative practices.

When designed with reflexivity and equitable governance, citizen science can advance inclusivity in ways technical mandates cannot. The UK's OPAL (Open Air Laboratories) programme, launched in 2007, not only involved citizens in environmental monitoring but also recognised them as co-authors (Davies et al., 2016). In Canada, the First Nations Food, Nutrition, and Environment Study developed repositories under Indigenous governance to retain control over sensitive knowledge (Chan et al., 2019). Similarly, the Arctic Indigenous Knowledge and Use of Sea Ice initiative embedded Inuit epistemologies into project design and interpretation (Gearheard et al., 2011). These examples demonstrate how careful design can turn inclusivity rhetoric into substantive democratisation, expanding Open Access to include authority, recognition, and shared decision-making.

At the same time, new challenges emerge. Ensuring data quality, equitable participation, and genuine influence over research priorities remains difficult. AI-driven verification tools enhance data reliability but are usually confined to well-funded projects, reinforcing disparities. UNESCO's (2021) global monitoring shows that socio-economic and geographic inequalities continue to restrict participation, particularly in low- and middle-income regions.

European initiatives such as the European Citizen Science Association (ECSA) guidelines, Luftdaten.info in Germany, and BioDiversity4All in Portugal show how participatory research can be embedded into governance frameworks. Horizon Europe and the European Green Deal explicitly integrate citizen science into policy, while France's Rapport Houllier and UNESCO's Recommendation on Open Science stress its role in equity and recognition of marginalised knowledge.

Yet, as Chapter 4 on metrics notes, institutionalisation can reproduce asymmetries when citizen science is reduced to a cheap data-collection tool. Analyses by Vohland et al. (2021) and Perelló et al. (2022) show that many large biodiversity monitoring projects in Europe centralise authority in academic institutions. Alternative models illustrate more balanced approaches: the Science Shops network in the Netherlands has, since the 1970s, responded to community research needs through co-designed projects that produce co-owned results. The Barcelona Citizen Science Office similarly co-develops projects with neighbourhood groups on urban issues, ensuring local participation from problem definition to dissemination (Perelló et al., 2022). In Africa, the African Open Science Platform's partnership with farmer organisations in Uganda demonstrates how agricultural monitoring can include local analysis and governance over data sharing (Onyancha et al., 2021).

Taken together, these examples show that the complexity of citizen science lies in its potential both to democratise and to reproduce hierarchies. Its integration with Open Science and Open Access is most effective when operationalised through co-design, shared governance, and mutual benefit, ensuring that openness leads to equitable changes in how knowledge is produced, disseminated, and valued.

10.2 Digital turn and ethical dilemmas

The digital transformation of scientific practice has reshaped not only research tools but also the social contracts of knowledge production, dissemination, and governance. This shift affects the integration of Open Science and Open Access with citizen science and participatory action research, raising fundamental questions of who participates, under what conditions, and with what power. As discussed in Chapters 3 (digital infrastructures), 4 (metrics), and 6 (institutionalisation), digital innovation has opened participatory channels while reinforcing new asymmetries.

Platforms such as iNaturalist (USA/EU), OpenStreetMap (global), and Pl@ntNet (France) show how crowdsourced data can advance knowledge and mobilise diverse communities. Their success reflects both digital affordances, faster aggregation, broader dissemination, interactive interfaces, and wider socio-political factors like rising environmental awareness and supportive policy frameworks. Yet, as Milan & Tréré (2020) and Albornoz & Chan (2020) note, these platforms also exemplify risks of data extractivism and governance concentration, with infrastructures often controlled by commercial or Northern institutions. Technology may

enable participation, but long-standing inequalities, language barriers, and epistemic hierarchies still determine whose knowledge counts.

These tensions are visible in projects like the EU-funded NextGEOSS, which improved environmental monitoring through open geospatial data but risks replicating technocratic participation if governance remains centralised and language access restricted (Bocquet, 2022; Rodríguez et al., 2021). Without local decision-making power, citizen science risks becoming symbolic rather than advancing epistemic justice.

The integration of AI and machine learning complicates matters further. Algorithms can filter, classify, and prioritise contributions, boosting efficiency but embedding opaque biases (Ananny & Crawford, 2018). Research on eBird's AI-assisted species identification shows that while participation expands globally, the tool privileges regions with more training data, underrepresenting biodiversity elsewhere (Sullivan et al., 2023). Similarly, citizen air-quality monitoring platforms like Sensor.Community use machine learning to aggregate data, yet filtering has disproportionately discarded readings from low-cost sensors in marginalised areas, creating environmental blind spots (Barbier et al., 2022). As noted in Chapter 8, technical expertise concentrated in a few actors, major tech firms and well-funded consortia, limits citizen influence. When AI systems decide what counts as “valid” data, entrenched hierarchies can be hidden beneath openness rhetoric.

Ethical dilemmas also intensify in high-stakes contexts. During COVID-19, participatory epidemiology platforms such as CORD-19 and CoronaDataSpende were hailed for openness but exposed fragile consent frameworks, particularly where private providers were involved (Taylor & Kim, 2023). The urgency of surveillance conflicted with long-term privacy, raising questions about commodifying sensitive data.

European responses attempt to balance openness with safeguards. The “Rapport Houllier” (2017), Spain's Open Science Strategy (2023), and Germany's National Research Data Infrastructure (NFDI) link access principles to participatory guidelines stressing co-design, fair sharing, and multilingual documentation. EOSC has integrated citizen science, yet barriers of access and complexity persist (Fecher & Friesike, 2021), highlighting the need for stronger governance reform.

Alternative governance models illustrate different approaches. AmeliCA in Latin America and the African Open Science Platform (AOSP) embed linguistic diversity, autonomy, and social justice into operations (Chan et al., 2023; Piron et al., 2021). These examples show how regional epistemologies can resist Anglo-American framings of openness.

Citizen-generated data in policymaking, from biodiversity mapping to urban planning, raises further questions about authority and representativeness. Political epistemology highlights the unresolved issues of who validates data, how dissent is treated, and whether lay expertise is genuinely integrated or merely instrumentalised (Callon et al., 2001; Jasanoff, 2004).

To avoid extractive dynamics, participatory digital infrastructures must embed co-governance and equity. Models such as science shops, living labs, and community data trusts demonstrate how shared authority can work. Examples include Barcelona Digital City, where citizen deliberation shapes smart city design, and the Ada Lovelace Institute's advocacy for participatory data stewardship.

The contrast between initiatives such as EOSC and AmeliCA underlines the diversity of inclusivity models, rooted in regional histories and political economies. Robust Open Science frameworks must therefore commit to local agency, multilingualism, ethical safeguards, and sustained public investment in non-commercial infrastructures. Without these, the digital turn risks reinforcing, rather than dismantling, the very inequalities Open Science seeks to overcome.

10.3 Bridging participation and power

The promise of Open Science to democratise knowledge production depends not only on digital tools, institutional commitments, or regulatory frameworks, but on the redistribution of epistemic power and authority. As highlighted in Chapters 2, 4, and 7, genuine inclusivity requires confronting the dominance of elite institutions and market logics in shaping research agendas, while embedding citizen science and participatory action research into governance structures rather than treating them as peripheral.

Despite political declarations and targeted funding incentives, many citizen science projects continue to operate within asymmetrical power relations. Evaluations of EU Horizon 2020 “Science with and for Society” (SwafS) projects, for instance, show that institutions and funders often define research questions, control methodologies, and determine recognition, leaving citizens primarily as data collectors. Similar patterns are seen in North American biodiversity networks, where volunteers provide observations but have little influence over analysis or authorship (Cooper et al., 2021). This dynamic reflects Irwin’s (2006) notion of the “institutional capture of participation,” where engagement is instrumentalised for legitimacy rather than redistributing decision-making power. Parallel findings from Latin American participatory urban planning show that citizen input is frequently solicited but seldom integrated into final policy documents (Perkins, 2020).

Concrete examples illustrate both potential and limitations. France’s *PartiCitaE* engages citizens in urban planning research; Germany’s *Bürger schaffen Wissen* (“Citizens Create Knowledge”) serves as a national platform coordinating citizen science projects; and the UK’s *Public Dialogue on AI* used deliberative forums and citizen juries to shape ethical guidance. These initiatives show that participatory advisory boards, citizen juries, and co-authorship protocols can give publics real influence. By contrast, assessments of SwafS projects reveal that many remained top-down, citing participation mainly for dissemination while excluding citizens from strategic planning (Felt et al., 2020).

Promising counter-models exist. The long-standing Science Shops in the Netherlands, and their adaptations in Denmark, Austria, and South Africa, respond directly to community-defined research needs through reciprocal partnerships. The Barcelona Science Policy Office and Bologna Urban Lab integrate citizen input into municipal governance, aligning policy with community-generated data. In Africa, the African Open Science Platform has partnered with farmer cooperatives in Uganda to ensure agricultural data is locally collected, analysed, and governed, with equitable control over sharing (Onyancha et al., 2021).

Methodologically, bridging participation and power requires integrating feminist and postcolonial epistemologies (Harding, 2008; Medina, 2013; Santos, 2018) that foreground lived experience, situated expertise, and non-Western ontologies. Examples include participatory health research in Canada led by

Indigenous women's councils, which redefine priorities based on community needs (Castleden et al., 2017), and agroecology initiatives in Brazil's Landless Workers' Movement, which combine scientific methods with traditional knowledge to shape agricultural policies (Pimbert, 2018). In South Africa, the "Decolonising Science" initiative integrates isiXhosa and isiZulu ecological concepts into biodiversity monitoring, showing how epistemic pluralism can enhance both data and ownership. As Chapter 8 notes, Open Science infrastructures often privilege well-funded, Anglophone institutions while sidelining community knowledge, oral traditions, and grey literature. Without interventions such as multilingual repositories, open peer review, and community licensing, access alone cannot address these imbalances.

Achieving genuine power-sharing therefore requires: (1) embedding co-creation in funding and governance criteria, as in the EU's "Widening Participation and Strengthening the ERA" calls; (2) redefining evaluation metrics to value societal impact and epistemic diversity, as trialled in the UK's REF impact case studies and France's HCERES pilots; (3) providing sustained public investment in non-commercial infrastructures, exemplified by Germany's Nationale Forschungsdateninfrastruktur (NFDI) and Canada's Digital Research Infrastructure Strategy; and (4) fostering institutional cultures that treat citizen science as an epistemic partner, not a public relations tool, as in Barcelona's integration of citizen-generated data into climate action plans. Within this framework, Open Access becomes part of a broader transformation, linking transparency with justice and dissemination with agency in knowledge production.

11. Empowering researchers and stakeholders in Open Science

11.1 Expanding and integrating stakeholder roles

While citizen engagement and participatory research are central to Open Science, focusing solely on them risks obscuring the equally critical roles of researchers and institutions, public administrations and policymakers, and economic actors. These groups control infrastructures, regulations, and funding streams that determine the feasibility, inclusivity, and sustainability of openness. Without their active integration, Open Science risks remaining symbolic and detached from the political economy of research. A balanced approach must interrogate incentives, power asymmetries, and governance logics so that frameworks reshape rather than reproduce existing structures.

Research institutions form the operational backbone of Open Science. They generate most primary data and oversee infrastructures for curation, dissemination, and preservation. Their ability to implement FAIR principles, adopt sustainable open access strategies, and join global consortia is decisive. Examples include CERN's open hardware licensing, which influenced engineering standards beyond physics; EMBL-EBI's free bioinformatics databases, foundational for genomics and drug discovery; the Max Planck Digital Library's transformative agreements, which reshaped publishing economics; and ECMWF's open reanalysis datasets supporting climate modelling. Yet many institutions lacking stable funding or data stewardship teams comply only superficially, depositing incomplete datasets, neglecting metadata, or restricting formats. Fecher et al. (2023) caution that without clear policies and sustained investment, open-data initiatives risk fragmentation. Durable practice requires skilled personnel, interoperable platforms, and cultures valuing openness.

Administrations and policymakers design the frameworks that enable or constrain openness. The Netherlands links funding to compliance; France's Second National Plan integrates openness into evaluation; Nordic states enable near real-time data sharing; Canada's Tri-Agency policy mandates repository deposit; and South Africa's 2022 policy sets phased targets. Horizon Europe embeds openness in evaluations, but enforcement remains uneven. Underinvestment in Eastern and Southern Europe contrasts with Nordic centralisation, showing how governance choices shape outcomes.

Economic actors also shape Open Science through partnerships, infrastructures, and standards. The Innovative Medicines Initiative (IMI, launched in 2008 as an EU–EFPIA joint undertaking) demonstrates pre-competitive collaboration but raises concerns over intellectual property. The European Battery Alliance coordinates standards for clean tech but prioritises competitiveness. GODAN fosters agricultural datasets yet raises concerns about corporate capture, while the Open Geospatial Consortium sets environmental data standards with uneven uptake. EU open banking APIs under PSD2 offer a model of portability relevant to Open Science. These cases highlight the need for governance that balances innovation with public value, mandating equitable access, transparency, and stewardship.

Inclusive governance requires clear decision-making powers, accountability, and enforceable standards. Finland's Open Science Coordination Office co-designs policies and tracks uptake with public dashboards. The UK's Alan Turing Institute codesigns AI ethics with regulators and firms, embedding safeguards. Canada's Digital Research Alliance co-manages infrastructures across universities, government, and industry. EOSC's governance board shows how multi-stakeholder models can mitigate conflicts of interest. Such frameworks must move beyond symbolic inclusion to operational accountability.

Recognition and reward systems must also shift. Researchers should be credited not only for publications but for repository contributions, governance roles, and community standards, as piloted in the Dutch Recognition & Rewards programme and the European Commission's assessment reform. Administrations should link evaluation to measurable outcomes such as reduced disparities and FAIR compliance. Economic actors should commit to benefit-sharing, ethical standards, and oversight, drawing on governance models like IMI and GODAN. Without such alignment, even sophisticated frameworks risk stagnation.

As earlier chapters argue, Open Science delivers systemic impact only when stakeholders act as genuine epistemic partners. Embedding openness into mandates, enforceable frameworks, and governance regimes that safeguard public value, while resisting enclosure and selective openness, is essential to realising its transformative potential.

11.2 Supporting early career researchers

The role of early career researchers (ECRs) in institutionalising Open Science is both indispensable and structurally conflicted. They are often presented as drivers of transformation, digitally adept, open to interdisciplinarity, and skilled in collaborative practices. Yet their capacity to enact meaningful change remains constrained by precarious contracts, rigid evaluation systems, and institutional cultures dominated by outdated excellence indicators.

Policy frameworks such as the European Commission's *Open Science Monitor* (2021), UNESCO's *Recommendation on Open Science* (2021), and the CoARA agreement (2022) increasingly recognise ECRs as central actors. Still, recognition rarely translates into enabling environments. The tension persists: ECRs are expected to embody Open Science values while assessed through legacy metrics that penalise such practices.

Survey data highlight this disjunction. A 2021 survey of 5,000 doctoral and postdoctoral researchers across the EU found that 78% felt pressured to prioritise high-impact journals, even when conflicting with openness; only 32% felt supported to share data, and just 41% felt free to post preprints without jeopardising publication opportunities (EC Open Science Monitor, 2021). Training and support vary widely: while over 80% of doctoral programmes in the Netherlands and Finland include Open Science components, fewer than 40% do so in Italy, Poland, or Spain. Such disparities make openness riskier for those with the least institutional power.

ECRs also face exclusion from governance. Most work on temporary contracts, lack access to infrastructure, and are absent from decision-making bodies. Contributions such as code, protocols, or metadata remain undervalued in evaluations. Studies show that even when ECRs acquire skills in reproducibility, open data, or open peer review, they often abandon them in favour of practices rewarded by hiring or funding panels (Baker

& Penny, 2022; Moher et al., 2018). One postdoctoral researcher quoted in EUA's *Recognition & Rewards* report (2023) noted: "I developed a full open dataset with detailed protocols for my PhD project, but my supervisor advised me to delay sharing it until after publishing in a subscription journal."

Economic and linguistic inequities deepen these dilemmas. In less-resourced institutions, APCs remain prohibitive. While diamond OA platforms such as *OpenEdition* in France and SciELO in Brazil offer alternatives, they are not systematically recognised in evaluation. Non-English-speaking researchers face additional barriers to visibility in global citation systems.

Despite constraints, ECRs drive many grassroots innovations. Initiatives such as ReproducibiliTea, *The Turing Way*, and The Carpentries were launched largely by doctoral or postdoctoral scholars. These communities provide training, mentoring, and open resources outside formal structures, filling institutional gaps. ECR-led workshops on open code, data curation, and reproducibility are now central to capacity-building.

Some institutions are beginning to respond. Ghent University, Université de Lausanne, and the Universitat Oberta de Catalunya have integrated Open Science literacy into doctoral curricula. The University of Helsinki credits open peer review, dataset publication, and open educational resources. Funders such as Belgium's FWO and the Netherlands' ZonMw now include open practices in fellowship evaluations.

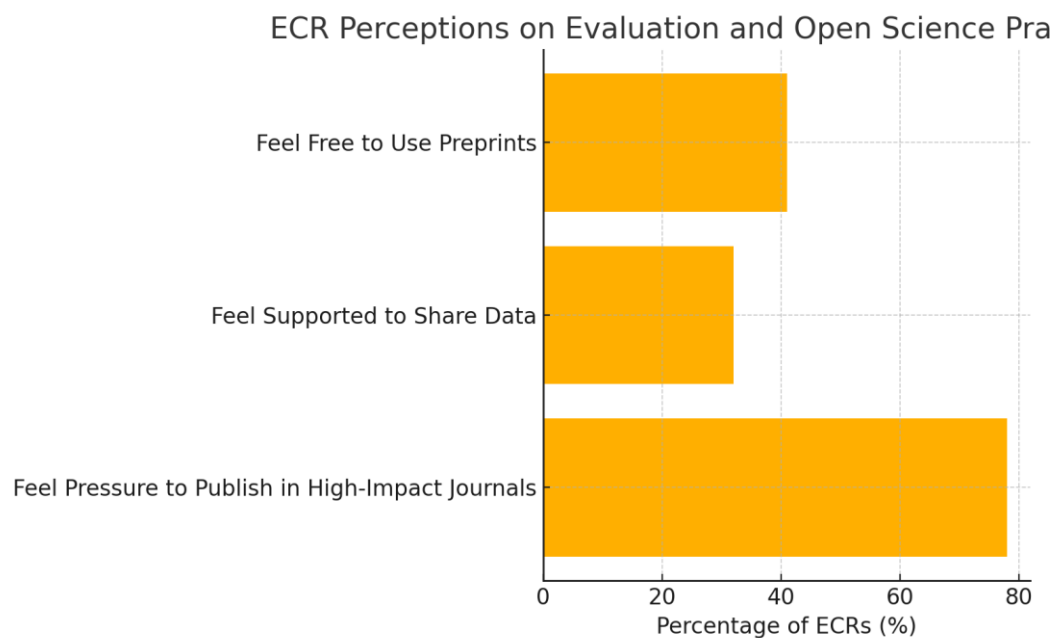
Yet evaluation reform remains the bottleneck. The CoARA implementation report (2023) shows that while many institutions sign declarations, few change hiring or promotion rules. Journal-based metrics continue to dominate, sidelining open datasets, community engagement, or infrastructure work. Thus, ECRs must choose between investing in openness or prioritising survival in competitive labour markets.

Resolving this requires structural change on multiple fronts: shifting evaluation frameworks toward plural criteria that reward transparency, collaboration, and societal impact; securing employment protections and recognition for non-traditional outputs; providing dedicated funding for ECR-led open projects; embedding Open Science as a core element of doctoral training; and ensuring ECR representation in governance. Without such reforms, their commitment risks remaining precarious and undervalued.

In sum, ECRs are not merely the "next generation" but already central operators of transformation, curating repositories, building reproducibility toolkits, and sustaining open communities. Supporting them is not only a matter of fairness but a strategic necessity for the future of equitable and robust scientific ecosystems.

Figure 7: ECR Perceptions on Evaluation and Open Science Practices in the EU (2021)

This chart presents the proportion of early career researchers (ECRs) in the EU who feel constrained by traditional evaluation systems versus those who feel institutionally supported in adopting open science practices.

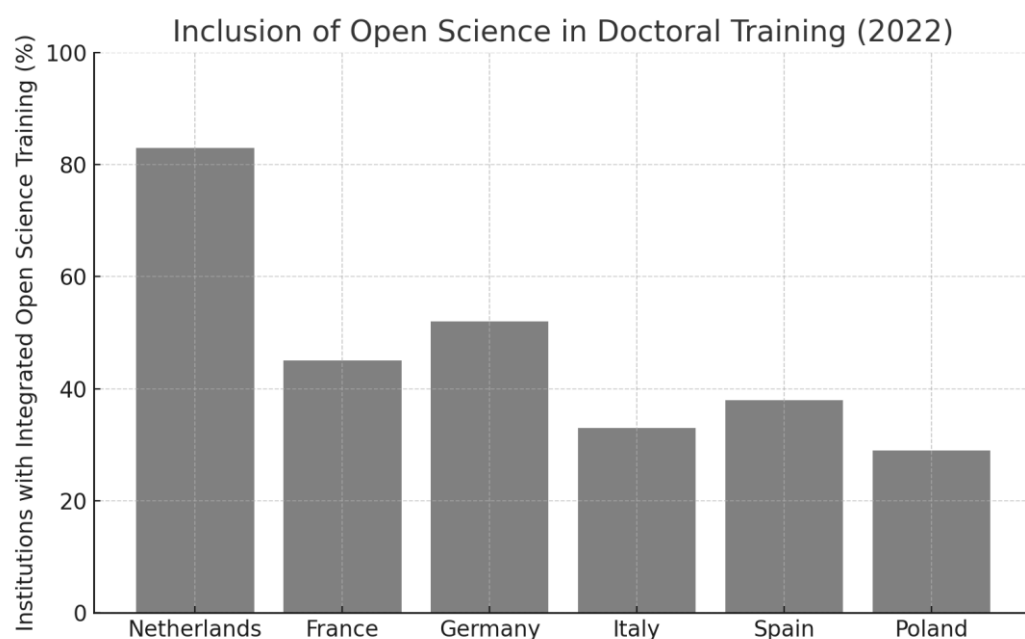


Source: European Commission, Open Science Monitor – ECR Module (2021).

<https://ec.europa.eu/research/openscience/index.cfm>

Figure 8: Proportion of Institutions with Integrated Open Science Training in Doctoral Programs (2022)

This chart compares the share of doctoral institutions in selected European countries that have formally integrated Open Science training components, based on national surveys and EUA reporting.



Sources: EUA (2022), Science Europe (2022), National Doctoral Education Reports.

<https://eua.eu/resources/publications/1012-recognition-and-rewards-towards-a-systemic-change.html>

Table 6: Selected Empirical References on ECRs and Open Science (with URLs)

This table summarises selected reports and studies highlighting key issues and reform dynamics related to early career researchers in Open Science, with direct URLs.

Title	Relevance for ECRs	URL
Recognition & Rewards programme, DORA, EUA (2023)	Partial institutional reform limits evaluation change	https://eua.eu/resources/publications/1012-recognition-and-rewards-towards-a-systemic-change.html
Doctoral Open Science integration disparities	Persistent regional inequality in Open Science training	https://op.europa.eu/en/publication-detail/-/publication/163e6b17-4273-11ed-92ed-01aa75ed71a1/language-en
Training programs for innovation	Entrepreneurial model marginalises epistemic plurality	https://hal.science/hal-04031350v1

(Ruano-Borbalan, 2023)		
CoARA & UNESCO on reforming evaluation	Evaluation reforms face implementation gap	https://coara.eu
European Commission Open Science Monitor (2021)	Training gaps reinforce structural asymmetries	https://ec.europa.eu/research/openscience/index.cfm

11.3 Beyond the rhetoric of capacity-building: towards strategic empowerment and institutional transformation in Open Science

Capacity-building has become one of the most frequently invoked terms in Open Science, Open Access, and Open Source policy. It appears in UNESCO’s *Recommendation on Open Science* (2021), Science Europe’s *Practical Guide to Capacity-Building* (2022), OECD frameworks (2023), and most national strategies. Yet the concept is contested. Advocates see it as essential for enabling participation in open research ecosystems; critics argue it often functions as “management speak” (Spicer, 2017), projecting ambition while avoiding questions of governance, resources, and accountability. Like “empowerment” or “stakeholder engagement” (Cornwall & Eade, 2010), capacity-building can be rhetorically inclusive while masking structural inequalities in power and resource distribution.

The term originated in the 1980s within development economics and international administration, replacing the “technical assistance” paradigm of post-colonial aid (Morgan, 2006). It was later adopted in health, education, and environmental policy before entering science policy via UNESCO, the World Bank, and the European Commission. This migration carried assumptions that “capacity” was lacking in certain contexts, often in the Global South, and abundant elsewhere. As earlier chapters noted, such framings can be reductive, overlooking that epistemic capacity also resides in situated knowledge and intellectual autonomy.

In Europe, capacity-building is often framed as strategic adaptation: equipping researchers, institutions, and firms to align with open practices while enhancing competitiveness and societal impact. France’s *Plan National pour la Science Ouverte* (2023–2027) funds Open Science officers, repositories, and multilingual platforms. Finland’s Open Science Coordination Office certifies data stewards and repository managers. Germany’s Nationale Forschungsdateninfrastruktur (NFDI) develops technical services, legal frameworks, and domain-specific training, embedding capacity across the research system.

These cases show that capacity-building goes beyond technical training. It involves governance reform, legal expertise, incentive redesign, and cross-sector networks. The European Open Science Cloud (EOSC) highlights this: interoperability requires not just infrastructure but also trained staff, clear governance, and sustainable

funding. Its Federated Data Stewardship framework links infrastructure with training, recognising that capacity lies as much in people and institutions as in technology.

Enterprises also play a growing role. The Innovative Medicines Initiative (IMI), already introduced earlier in the report, illustrates pre-competitive collaboration. Its EHDEN project created a federated network of health data sources, established technical standards, and ran cross-sector training academies on data interoperability, GDPR compliance, and ethics. CERN's Open Data Portal, hosted through partnerships with commercial cloud providers such as Amazon Web Services, combines high-availability infrastructure with shared development of access and security standards. Red Hat has supported the Galaxy Project by optimising open-source bioinformatics workflows, while GitHub's *GitHub for Research* programme provides tailored repositories and CI/CD tools for academic teams (Chue Hong et al., 2021; Katz et al., 2021).

However, private-sector involvement can create dependencies, embed proprietary standards, or skew priorities. Safeguards, transparent licensing, public oversight, and shared governance, are needed to align collaboration with public value. Without these, partnerships risk enclosure rather than capacity-building.

Despite progress, much capacity-building remains focused on “compliance readiness”: meeting mandates for FAIR data, OA publishing, or data management. This technocratic approach neglects structural equity and epistemic diversity. Science Europe (2023) reports over 80% of Northern and Western European institutions have FAIR-compliant infrastructures, compared to fewer than 40% in Central and Eastern Europe. Research software support is similarly stratified: elite universities employ data librarians and research software engineers, while smaller institutions cannot. Capacity to “be open” thus reflects existing privilege, creating a two-tier system.

A more ambitious view treats capacity as an ecosystem property: combining human resources, infrastructure, organisational competence, and epistemic diversity. This means investing in permanent staff (data stewards, multilingual editors, legal experts), interoperable repositories, and recognition of non-traditional expertise, including citizen scientists and civil society actors. Examples include France's *Recherche Data Gouv* with thematic training networks, the Netherlands' SURF workshops and hosting services, and the UK's Alan Turing Institute co-developing open-source AI tools with industry.

In open-source research, sustainability is key. Without maintainers, many projects become “abandonware.” Capacity-building here requires long-term funding for software engineering, governance training, and adoption of open licensing.

Ultimately, capacity-building must shift from fragmented, project-based efforts to embedded, durable investments. It should be integrated into research budgets, institutional evaluations, and cross-sector governance. Only then can Open Science move beyond privilege and become a structural reality, anchored in capacities that are co-created, jointly governed, and resilient over time.

12. Recommendations for policymakers

This chapter distills the analytical insights developed throughout the report into a set of concrete, policy-oriented recommendations for advancing Open Science in ways that are both ambitious and practicable. It serves as the gateway to two substantive sections: the first outlines key policy measures to strengthen governance, infrastructure, and capacity (Section 12.1), and the second focuses on fostering inclusive, sustainable implementation and long-term impact (Section 12.2).

The recommendations are grounded in comparative evidence, case studies, and policy frameworks discussed earlier in the report. They address the enabling conditions that must be nurtured, such as robust governance, adequate funding, and equitable capacity-building, as well as the systemic barriers that must be dismantled, including entrenched inequalities, fragmented infrastructures, and narrow evaluation metrics. Recognising the diversity of national, regional, and disciplinary contexts, they are designed to be adaptable, offering policymakers, institutions, and stakeholders a strategic repertoire of interventions.

The goal of this chapter is to provide a coherent bridge from the report's analytical foundations to concrete, actionable strategies, such as reforming research evaluation metrics, investing in multilingual and regionally governed repositories, and creating cross-sector governance platforms, so that Open Science becomes not only technically viable but also socially embedded, equitable, and resilient.

12.1 Aligning academic incentives: confronting structural lock-ins and scaling viable alternatives

The sustainability of Open Science depends not only on infrastructure and governance but also on reforming the academic incentive system. This is among the most critical and politically sensitive issues in the Open Science agenda. Across the report, particularly in Chapters 3 (fragile and donor-dependent infrastructures), 4 (misaligned metrics and evaluation cultures), 5 (capacity and inclusivity gaps), 6 (policy incoherence), and 10 (stakeholder engagement and capacity-building), a fundamental contradiction emerges: while policies increasingly demand openness, academic careers, funding, and prestige remain tied to closed, exclusionary, and narrowly quantified evaluation systems. This contradiction limits adoption and reinforces inequalities between disciplines, generations, and regions.

A central obstacle is the persistence of bibliometric proxies, impact factor, h-index, journal quartiles, as dominant criteria in hiring, promotion, and grants. As shown in Chapter 4, such metrics value journal prestige over content, quantity over quality, and English-language outputs over linguistic diversity. They marginalise collaborative, socially engaged, or experimental research. EUA (2022) and CoARA (2023) show that although many institutions endorse reform rhetorically, implementation is inconsistent. SSH fields and early career researchers are particularly disadvantaged, since their outputs, monographs, policy briefs, open datasets, are often excluded from high-impact journals.

As Chapter 11 highlights, early career researchers and postdoctoral scholars often lack protection or recognition to adopt Open Science practices. Expectations around data sharing, open access, and engagement rarely translate into evaluation credit. These efforts require additional labour without institutional reward.

Territorial variation further complicates reform. In the Netherlands and Germany, coordinated strategies, such as the Dutch Recognition & Rewards programme, have broadened criteria to include openness, teaching, and societal impact. In contrast, Italy and Hungary remain dependent on hierarchical systems and journal metrics. Structural lock-ins persist: ministry-controlled evaluation systems (Italy, Romania), journal-based KPIs (Hungary, Poland), and weak collective bargaining in precarious labour markets (Spain, UK post-REF). These barriers demand collective action, legal innovation, and coordinated reform across funders, universities, and ministries. Where national agencies support reform (Finland, France, Netherlands), the priority is scaling pilots. In weaker coordination contexts (Central and Eastern Europe), EU conditionalities or regional coalitions (e.g. the Visegrad Group) may offer leverage. In the UK, REF 2021 and the Future Research Assessment Programme (FRAP) have opened debate on more inclusive definitions of “excellence,” though contested in practice.

This report identifies five interdependent levers for reform:

- Redefining excellence through qualitative assessment: narrative CVs, field-sensitive peer review, and contribution-based criteria. France’s CNRS dossier format now includes open access, data curation, and engagement, echoing European Commission steps to integrate qualitative indicators in Horizon Europe.
- Recognising diverse outputs: Finland and Norway include datasets, software, preprints, and citizen science reports in hiring criteria. Austria’s BMBWF guidelines link promotion to open contributions.
- Protecting and incentivising early career engagement: ERC Starting Grants, MSCA Fellowships, and initiatives in Belgium (FWO) and Sweden (VR) could expand to reward ECRs active in Open Science infrastructures.
- Rewarding collective and transdisciplinary work: the Flemish Interuniversity Council and the Swiss National Science Foundation have developed tools for evaluating collaborative and multi-institutional contributions.
- Aligning policies across the ecosystem: national plans in France, Slovenia, and Portugal should harmonise funder mandates, evaluation, and careers. The European Agreement on Reforming Research Assessment (2022) and Germany’s Coalition for Advancing Research Assessment offer blueprints.

Observatories and monitoring systems can make reform operational. France’s Open Science Barometer tracks access across disciplines and informs the Second National Plan. In Belgium, ECOOM analyses evaluation practices to support reforms in Flanders. At EU level, the Open Science Monitoring Framework and EOSC Observatory provide comparative tracking. In the UK, the Knowledge Exchange Framework (KEF) includes openness indicators, while FRAP explores broader impact metrics.

These initiatives, while fragmented, show that reform is feasible and policy-relevant. Without such frameworks, commitments risk remaining aspirational. Metrics reform, career restructuring, and recognition of knowledge

diversity are not peripheral, they are preconditions for systemic change and must be embedded in institutional and national governance.

12.2 Blueprint for Action: co-constructing systemic and reflexive Open Science policies

The findings of this report converge on a central insight : Open Science cannot be scaled sustainably through technical fixes or normative declarations alone. It requires coordinated transformations in governance, incentives, institutional infrastructures, and epistemic cultures. This final section outlines a strategic blueprint for action, grounded in empirical evidence and the differentiated challenges identified across the European research landscape. Each recommendation is illustrated with existing practices that demonstrate feasible implementation.

Anchor Open Science in institutional governance frameworks

Universities and research institutions must move beyond symbolic declarations and integrate Open Science into their core governance. KU Leuven and the University of Helsinki, for example, have created vice-rectorships for Open Science, ensuring coordination across infrastructure, evaluation, and training. The CNRS in France established the Comité pour la science ouverte, which oversees national strategy and provides templates for institutional action. Embedding Open Science requires:

- Creating senior leadership roles (vice-rectors, committees) dedicated to Open Science.
- Establishing offices responsible for training, infrastructure, and monitoring.
- Integrating Open Science into ethics and data governance frameworks.

Coordinate national and EU-level policy alignment

Policy misalignment undermines uptake. France's Plan National pour la Science Ouverte and Finland's Open Science and Research Initiative are linked to ERA goals, while Horizon Europe embeds openness as a cross-cutting requirement. Greater alignment can be achieved by:

- Supporting national Open Science strategies (Finland, France, Slovenia) aligned with ERA and EOSC.
- Strengthening coordination through EU Council conclusions and the ERA Forum.
- Introducing conditionalities in EU research funding tied to openness and inclusiveness.

Support infrastructural sovereignty and diversity

Many practices rely on infrastructures dominated by commercial actors. Public, federated repositories such as HAL (France), SciELO and Amelica (Latin America), and RECOLECTA (Spain) provide alternatives. Investments in persistent identifiers (ORCID, DataCite) and FAIR metadata frameworks (via EOSC Interoperability) enable openness while respecting diversity. Priorities include:

- Scaling regional platforms that support multilingual and non-APC publishing.
- Funding public repositories and open metadata systems.

- Ensuring interoperability across domains and disciplines.

Align evaluation and career systems with Open Science

As shown in Section 11.2, reward systems remain misaligned. Austria's BMBWF includes open access in performance agreements; the Dutch Recognition & Rewards programme broadens academic excellence criteria; France's CNRS rewards data sharing and preprints. Practical measures include:

- Recognising diverse outputs (datasets, software, policy briefs) in CVs and funding.
- Incentivising collective and cross-sectoral research.
- Embedding Open Science indicators into evaluations at national and institutional levels.

Empower early career researchers and underrepresented actors

ECRs and marginalised groups need targeted support. The EOSC Skills Working Group has created multilingual training curricula, and doctoral schools in Spain and Ireland have introduced Open Science modules. Agencies such as FWF Austria and Sweden's VR fund collaborative open publication plans. Actions should:

- Provide grants and fellowships for ECR-led Open Science projects.
- Support community-based, Indigenous, and non-anglophone scholarship.
- Embed Open Science training in doctoral and master's programmes.

Establish monitoring and accountability mechanisms

Transparent monitoring is key. France's Baromètre de la science ouverte tracks open access by discipline, Belgium's ECOOM provides dashboards linking publication diversity to evaluation practices, and the EOSC Observatory enables cross-country comparisons. Steps include:

- Requiring transparent reporting of compliance.
- Funding observatories with shared, standardised metrics.
- Tracking impacts on equity, participation, and knowledge diversity.

Foster participatory and reflexive policy design

Sustainable policy reform depends on co-design. OpenAIRE's roadmap toolkit facilitates stakeholder consultations; Slovenia's National Open Science Committee includes researchers, librarians, funders, and policymakers. Feedback loops piloted by the Dutch Research Council and Germany's Open Access Monitor ensure adaptability. Recommendations include:

- Creating deliberative bodies that include researchers, students, and communities.
- Applying co-design methodologies to shape strategies.
- Implementing feedback loops to revise policies dynamically.

This blueprint does not propose a universal formula. It recognises that countries, disciplines, and institutions face distinct conditions. What unites these strategies is the recognition that Open Science must be co-constructed with the communities it seeks to transform. Its future depends not only on access and infrastructure but also on democratic governance, accountability, and the redistribution of epistemic power.

Conclusion: towards sustainable Open Science ecosystems

Open Science stands at a critical and complex juncture. This report has examined its rise as both a transformative vision for reconfiguring global knowledge systems and a contested policy domain shaped by competing economic, political, and epistemic agendas. Its sustainability depends not only on expanding infrastructures but also on understanding it as part of a broader ideological and institutional transformation of the knowledge production regime. Open Science's discourse and implementation have, in many respects, already succeeded in reshaping representations of science: reframing it as a more transparent, collaborative, and responsive system aligned with contemporary economic doctrines of innovation, managerial models of performance, and political ideals of deliberation and empowerment. This ideological embedding has enabled its rapid uptake but has also made it susceptible to the same limitations and contradictions as these broader societal currents.

Across the chapters, the evidence is unequivocal: while infrastructures, declarations, and policies proliferate, the deeper political, epistemic, and social foundations remain fragile. This is not merely a matter of technical implementation, it is a governance and justice challenge that must confront entrenched asymmetries in global science, the unequal geography of knowledge production, and the political economy of research. Open Science's focus on capacity building, empowerment, and stakeholder engagement, mirroring the language of international development, often operates at a psychological and organisational level that emphasises individual agency while deflecting attention from questions of power, domination, and the structural fields of force that shape research systems. Social science critiques have long shown that such discourses risk creating an "illusion of empowerment" that masks the persistence of hierarchies.

The central insight is that openness is not self-justifying. Its legitimacy rests on whose knowledge is valued, who sets research agendas, and how benefits are distributed. This requires structural guarantees: legal frameworks to protect knowledge commons, funding models that prioritise public value over profit, and evaluation systems that reward epistemic diversity, collaboration, and societal relevance rather than prestige metrics. Furthermore, disciplinary diversity must be recognised: a FAIR-principle, data-centric model may serve genomics or climate modelling but is ill-suited to history, anthropology, or Indigenous studies, where multilingualism, community co-governance, and non-digital dissemination are critical.

Examples from this report show how alignment between policy, infrastructure, and culture can succeed. France's *Plan National pour la Science Ouverte* embeds Open Science officers within universities, secures repository funding, and integrates training into academic careers. Latin America's AmeliCA provides a multilingual, no-APC publishing infrastructure governed by regional academic networks, resisting APC-driven marketisation. The European Open Science Cloud has achieved cross-border technical interoperability but still struggles with governance tensions between EU-level coordination and national autonomy. In biomedicine, the Innovative Medicines Initiative's EHDEN project built joint capacity across universities, public health agencies, and pharmaceutical companies, creating shared data models, governance frameworks, and training programmes that improved both scientific rigour and policy uptake. CERN's open data partnerships with

commercial cloud providers demonstrate that industry collaboration can deliver technical capacity while preserving open access principles.

Yet these cases remain exceptions. Many national strategies treat Open Science as an auxiliary technical agenda rather than as a systemic reorganisation of science–society relations. Proprietary analytics platforms continue to shape evaluation, embedding compliance logics that privilege well-resourced institutions and narrow epistemic space. Without deliberate integration into governance reform and equitable funding strategies, Open Science risks hardening into a compliance-driven label that masks structural inequities, reinforces dependency, and limits transformative potential.

Drawing together the key findings and critical themes woven throughout the report, the overarching message is that Open Science must be governed as a living, negotiated institution, socially embedded, politically contested, and continuously redefined in light of shifting conditions. Sustainability is not merely operational continuity; it is the capacity to renegotiate the terms of scientific legitimacy, inclusion, and public value, while critically interrogating the ideological frameworks within which it operates.

The path forward demands a decisive break from rhetorical endorsement toward structural reorganisation. It calls for sustained public investment, binding governance commitments, and an unambiguous orientation toward epistemic justice. Only under these conditions, acknowledging both the achievements of Open Science in reshaping the discourse of knowledge production and the unresolved power asymmetries it must still confront, can it realise its promise as a shared, equitable, and resilient global practice capable of addressing the intertwined challenges of knowledge production, democratic governance, and societal transformation.

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