

Leveraging Open Source Technologies as a Techno-regulatory Strategy to Advance Digital Sovereignty

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Abstract

This chapter analyses open source as a techno-regulatory strategy for advancing digital sovereignty, defined as “the capacity to understand, develop, and regulate digital technologies and thereby exercise self-determination and control over digital assets”. We argue that open source is increasingly leveraged as a strategy to undermine competitors, shifting where value is captured. Hence, open source should not be understood as in opposition to Intellectual Property Rights (IPRs) but as an ecosystem built upon them: open licenses require a functioning IPRs to be enforceable, and they reconfigure rather than abolish exclusive rights, opening alternative possibilities for transparency, collaboration, and redistribution. Crucially, we contend that open source is typically mobilized as a complement to proprietary strategies, not a substitute for them. Even where code or artificial intelligence model weights are open, actors continue to build power by owning knowledge assets, including trade secrets, tacit knowledge, proprietary datasets, and compute, so that openness frequently relocates value capture to adjacent layers of the stack rather than dissolving it. We argue that the capacity of openness to strengthen sovereignty depends less on the license than on the governance, industrial, and capability conditions surrounding it. After having discussed how large technology corporations have successfully leveraged open source, we offer three cases to illustrate how our findings apply to state policy through a graduated logic. Brazil shows how open licenses secure legally irrevocable access as a defensive shield, yet access without domestic capability merely relocates dependency. South Korea shows how embedding open source within developmental-state industrial policy converts access into co-development capability and export strength. India shows how open, modular Digital Public Infrastructure can be turned into standard-setting power, exporting not only software but a model of digital governance. In conclusion, we emphasize that for emerging economies – and all those who may be considered as “developing countries” in digital terms, i.e. most countries – , open source becomes sovereignty-enhancing only within a long-term, patient and focused ecosystemic strategy combining openness with sustained investment in institutions, skills, and industrial capabilities.

1. Introduction

Digital sovereignty has become one of the defining concepts in contemporary debates on technological governance. Yet the concept remains contested, not least because sovereignty in the digital environment cannot be reduced to territorial control over technological assets. Building on Belli's definition of digital sovereignty as “the capacity to understand how digital technologies work, to develop and regulate them effectively, thus exercising self-determination, power and control over digital assets,”¹ this chapter adopts a capacity-oriented and relational understanding of digital sovereignty. Hence, we situate this concept not merely as formal control over specific technologies but as an assemblage of agency, regulation, and systemic capability that enables actors to shape the digital ecosystems in which they operate without undue dependency on extrinsic powers.

From this perspective, open-source technologies can be seen as conducive of the structural power² that enables digital sovereignty. The concept of structural power refers

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¹ Luca Belli, 'Building Good Digital Sovereignty through Digital Public Infrastructures and Digital Commons in India and Brazil' (T20 India 2023); Luca Belli, 'To Get Its AI Foothold, Brazil Needs to Apply the Key AI Sovereignty Enablers (KASE)' in S Feldstein (ed), *New Digital Dilemmas: Resisting Autocrats, Navigating Geopolitics, Confronting Platforms* (Carnegie 2023); Luca Belli, 'BRICS countries and AI sovereignty: Introduction to Thematic Section' (2024) 34 AJIC 1, 1–6; Belli, L. (2025). Exploring the Key AI Sovereignty Enablers (KASE) of Brazil, to Build an AI Sovereignty Stack. In: Luca Belli and Walter B Gaspar (eds), *The Quest for AI Sovereignty, Transparency and Accountability* (Springer-Nature 2025); Luca Belli and others, *Soberania Digital e Inteligência Artificial no Brasil: Rumo à autonomia tecnológica* (Lumen-Juris 2026); Luca Belli & Ahmad Bhinder, 'Cooperative Digital Sovereignty and Artificial Intelligence: Promoting Resilience, Strategic Openness and Self-Determination. (Digital Cooperation Organization 2026)

² The concept of structural power is developed by Susan Strange in *States and Markets* (1988). A useful metaphor to understand this concept is that of a labyrinth: actors possessing structural power do not merely navigate the maze more effectively; they design it, deciding where the walls stand, which doors remain open, and which paths are available. Others remain free to move, but only within an architecture they neither created nor control. In the digital economy, this concept helps explain how dominant technology firms exercise a form of transnational private ordering by designing the technical, legal, and economic infrastructures upon which governments, businesses, and citizens increasingly depend, illustrating how

not in the ability to influence isolated decisions, but in the capacity to shape the institutional and technological structures within which those decisions are made. In the digital economy, such structures are embodied in software architectures, technical standards, cloud infrastructures, and the contractual terms of service.³ Together, these elements constitute a form of private ordering that enables corporate actors to exercise quasi-legislative, quasi-executive, and quasi-judicial functions over digital ecosystems.⁴ By making core technologies transparent, modifiable, and interoperable, open-source strategies can partially rebalance this distribution of structural power, reducing dependency on proprietary ecosystems and enabling a broader range of public and private actors to understand, adapt, govern, and ultimately exercise greater control over critical digital infrastructures. Open source alone, however, does not eliminate structural asymmetries. As we will discuss in the next sections, its sovereignty-enhancing potential depends on being embedded within broader governance, regulatory, industrial, and capacity-building strategies.

Furthermore, as an introductory clarification, the authors wish to reiterate that digital sovereignty must not be understood as synonymous with digital isolationism or technological autarky. On the contrary, based on the orientation developed in previous research⁵ we argue that digital sovereignty refers to the ability of states, organizations, and communities to exercise meaningful agency over the development, governance, and use of digital technologies – including as a tool of regulation – across the interconnected layers of data, software, hardware, networks, and the institutional arrangements that govern them. Within this analytical framework, open-source technologies should be understood not merely as software development methodologies but as a techno-regulatory strategy capable of advancing digital sovereignty in multiple ways.

On the one hand, open-source licensing promotes transparency, collaborative innovation, interoperability, and the redistribution of technological capabilities, reducing barriers to entry and enabling a wider range of actors to inspect, modify, adapt, and govern digital technologies, thus significantly contributing to increasing the quality of such technologies.⁶ These characteristics can strengthen digital sovereignty by expanding

structural power can translate into a de facto form of private sovereignty. See Susan Strange, *States and markets* (1st edn, Continuum 1988); Luca Belli *Structural Power as a Critical Element of Digital Platforms' Private Sovereignty* (published in *Constitutionalising Social Media*, Hart 2022).

³ Min Jiang and Luca Belli, ‘Contesting Digital Sovereignty: Untangling a Complex and Multifaceted Concept’ in Min Jiang and Luca Belli (eds), *Digital Sovereignty in the BRICS Countries: How the Global South and Emerging Power Alliances Are Reshaping Digital Governance* (Cambridge University Press 2025) 1–38.

⁴ *Supra*, note 2.

⁵ See, particularly, *supra*, note 1.

⁶ Eric S Raymond, *The Cathedral and the Bazaar: Musings on Linux and Open Source by an Accidental Revolutionary* (rev edn, O'Reilly Media 2001).

technical autonomy, reducing vendor lock-in, and facilitating the development of domestic capabilities.⁷ On the other hand, open source has increasingly been employed as a strategic market instrument by dominant actors seeking to undercut competition, shift where value can be captured, and shape market standards through technology. By openly releasing selected components of the technological stack, firms can encourage widespread adoption of their technologies, establish de facto technical standards, shape entire innovation ecosystems, and ultimately reduce competitors' ability to impose alternative proprietary standards.⁸ As we will discuss, this use is also strategic to increase the private digital sovereignty of the specific corporation leveraging open source to undermine competitors and cement its market position.

Indeed, rather than eliminating competitive dynamics, it often shifts competition from the ownership of software itself to adjacent layers of the digital ecosystem – including cloud infrastructure, AI services, proprietary datasets, specialized hardware, and complementary platforms – where value capture remains highly concentrated. Hence, we argue that open source can simultaneously foster openness and reinforce market leadership and in both case this use has a direct relationship with the capacity to construct one's digital sovereignty. This dual character demonstrates that open source cannot be assessed in isolation from the broader political economy of digital technologies. Its contribution to digital sovereignty depends less on the openness of the code than on the governance structures, industrial strategies, institutional capacities, and market conditions within which it is deployed.

Accordingly, this chapter argues that open source should be understood as one component of a broader techno-regulatory strategy aimed at enhancing digital sovereignty by combining openness, interoperability, and capability building while remaining attentive to the new forms of dependency and concentration that strategic openness itself may generate.

1.1. Open Source: Principles and Legal Regimes

Open source refers to a legal, technical, and governance model through which software, hardware designs, AI models, and associated documentation are made available under licences that grant users the freedom to access, inspect, use, modify, and redistribute

⁷ Luca Belli and others, *Soberania Digital e Inteligência Artificial no Brasil: rumo à autonomia tecnológica* (Lumen Juris 2026).

⁸ Alice Pannier, ‘Software Power: The Economic and Geopolitical Implications of Open Source Software’ (Études de l’Ifri, Ifri, December 2022); Kevin Boudreau, ‘Open Platform Strategies and Innovation: Granting Access vs. Devolving Control’ (2010) 56(10) *Management Science* 1849.

technological artefacts.⁹ Far from existing outside the intellectual property (IP) system, open source is enabled by it. Licences such as the GNU General Public License (GPL), MIT License, and Apache License rely on copyright law to transform exclusive rights into legally enforceable mechanisms for collaborative production and redistribution.¹⁰ Rather than abolishing IP, they reconfigure it to facilitate cumulative innovation, transparency, and shared technological development.

As emphasized in the previous section, this chapter argues that open source should be understood not simply as a software development methodology but as a techno-regulatory strategy capable of strengthening digital sovereignty. By promoting transparency, interoperability, and collaborative innovation, open-source ecosystems reduce barriers to technological participation, facilitate knowledge diffusion, and enable public institutions, firms, and research communities to develop greater agency over critical digital infrastructures. However, major technology firms can also deploy open software and open-weight models as strategic tools aimed at enabling the migration of value creation and extraction towards layers of the technology stack that remain defensible. Importantly, both the participatory and strategic characteristics of open source extend beyond software to encompass AI models, open hardware architectures, technical standards, and other foundational components of digital ecosystems.

Conspicuously, literature has consistently emphasized that open-source ecosystems reshape innovation dynamics by enabling distributed collaboration, modular technological development, and interoperability across different layers of the digital stack.¹¹ By lowering switching costs and mitigating vendor lock-in, they can reduce structural dependencies created by proprietary technologies and foster more competitive and resilient markets. From this perspective, open source can function as an important instrument for operationalizing digital sovereignty, particularly when embedded within broader governance frameworks that articulate the promotion of institutional capacity, industrial development, and open standards.

At the same time, this article emphasizes that open source should not be romanticized as an inherently decentralizing force. As we illustrate in section 2.2. and 2.3, increasingly,

⁹ Karl Fogel, *Producing Open Source Software: How to Run a Successful Free Software Project* (2nd edn, O'Reilly Media 2017).

¹⁰ Joseph Feller and Brian Fitzgerald, *Understanding Open Source Software Development* (Addison-Wesley 2002); Steven Weber, *The Success of Open Source* (Harvard University Press 2004).

¹¹ Steven Weber, *The Success of Open Source* (Harvard University Press 2004); Josh Lerner and Jean Tirole, ‘Some Simple Economics of Open Source’ (2002) 50(2) *Journal of Industrial Economics* 197; Manuel Hoffmann, Frank Nagle and Yanuo Zhou, ‘The Value of Open Source Software’ (Harvard Business School Strategy Unit Working Paper No 24-038, 2024) <https://doi.org/10.2139/ssrn.4693148>.

dominant digital firms strategically release selected components of their technological stacks under open-source licenses to accelerate market adoption, establish de facto technical standards, and expand their ecosystems while preserving control over higher-value complementary assets, including cloud infrastructure, proprietary datasets, specialized hardware, digital platforms and AI services.

Consequently, it would be incorrect to argue that openness inherently redistributes power. Rather, it might be more correct to emphasize that it frequently relocates value capture to adjacent layers of the digital economy. Whether open source ultimately strengthens digital sovereignty and who are the ultimate beneficiaries – or digital sovereigns – created by this process therefore depends not only on licensing choices or by the existence of decentralized communities of experts enabling collaboration and peer-revision. It substantially depends also on the surrounding governance arrangements, industrial policies, market structures, and institutional capabilities that determine who is able to meaningfully understand, adapt, govern, and benefit from the technologies made available.

Crucially, our research illustrates that the relationship between open source and sovereignty is ambivalent. On the one hand, open source can dismantle dependencies that are enforced through IP rights, enabling actors to avoid monopolistic control over essential technologies. On the other hand, open source can be co-opted by dominant firms as a strategic tool to consolidate value in adjacent segments of the technology stack, preserving or even amplifying market power.

1.2. A Pragmatic Approach: Articulating Intellectual Property and Open Source to Build Digital Sovereignty

Both proprietary technologies protected by intellectual property rights (IPRs) and open-source alternatives, promising greater autonomy, have a central role in building digital sovereignty. However, while IP regimes undoubtedly shape the distribution of technological power, and open source can reduce barriers created by exclusive rights, neither provides a sufficient basis for achieving digital sovereignty. A more pragmatic approach requires recognizing that the capacity to understand develop and control digital technologies requires a careful mix of IPRs and open source.

Traditional IPRs such as copyrights, patents, trademarks, and design rights remain important mechanisms for appropriating innovation and incentivizing investment. In the AI ecosystem, patents continue to play a significant role in semiconductor technologies, specialized hardware, and certain algorithmic techniques, while copyright governs software code, datasets, and model outputs in many jurisdictions. Yet the most strategically valuable assets are increasingly protected through mechanisms that fall

outside the traditional intellectual property framework or that, albeit part of the bundle of IP rights, function under different premises. Trade secrets¹², confidential know-how, proprietary datasets, engineering expertise, and organizational capabilities have become central sources of competitive advantage. Unlike patents, which require public disclosure in exchange for exclusivity, trade secrets derive their value precisely from remaining undisclosed.

This distinction has profound implications for digital sovereignty. Indeed, even where software is released under an open-source license, many of the capabilities required to reproduce, maintain, or improve complex digital systems remain inaccessible. Frontier AI models provide a clear illustration. A company may publish the model weights or source code while withholding the datasets used for training, the data-cleaning methodologies, reinforcement learning pipelines, evaluation benchmarks, safety procedures, or infrastructure optimization techniques.¹³ These elements frequently constitute the most valuable intellectual assets, and they are commonly protected as trade secrets rather than through formal intellectual property rights.

The same logic applies to advanced hardware. Although aspects of processor architectures or hardware designs may be publicly documented or even released under open hardware licenses, the tacit knowledge required to manufacture advanced semiconductors cannot simply be licensed or downloaded.¹⁴ Semiconductor fabrication depends upon decades of accumulated engineering expertise, highly specialized production processes, sophisticated quality control systems, and complex supplier relationships. These capabilities are embedded within organizations rather than legal rights. They are learned through experience, accumulated incrementally, and transferred

¹² Legal doctrine remains divided on whether trade secrets qualify as a distinct form of IPRs or belong properly to contract, tort, or unfair competition law. This ongoing classification debate stems from several factors: (i) IP scholars routinely study and analyze trade secrets in direct comparison and contrast with traditional statutory rights like patents, evaluating their overlapping functions in incentivizing innovation; (ii) international legal frameworks, most notably Article 39 of the WTO TRIPS Agreement, formally encompass "undisclosed information" within the broader architecture of IPRs, while anchoring its enforcement mechanism in general obligations against unfair competition; and (iii) jurisdictional approaches vary significantly, with several legal systems treating trade secrets as fully recognized proprietary IPRs and designating specialized intellectual property courts to adjudicate trade secret disputes. Consequently, scholarly literature reflects contrasting theoretical positions regarding whether trade secrets should be conceptualized inside or outside the strictly defined boundaries of IPRs. See e.g. Robert G Bone, 'A New Look at Trade Secret Law: Doctrine in Search of Justification' (1998) 86 Cal L Rev 241; Lemley, Mark A. "The Surprising Virtues of Treating Trade Secrets as IP Rights." *Stanford Law Review*, vol. 61, no. 2, 2008, pp. 311–353.

¹³ Rishi Bommasani and others, The Foundation Model Transparency Index v1.1: May 2024 (Stanford Center for Research on Foundation Models 2024) <https://arxiv.org/abs/2407.12929>; David Gray Widder, Meredith Whittaker and Sarah Myers West, 'Why "Open" AI Systems Are Actually Closed, and Why This Matters' (2024) 635 Nature 827 <https://doi.org/10.1038/s41586-024-08141-1>.

¹⁴ David J Teece, 'Profiting from Innovation in the Digital Economy: Enabling Technologies, Standards, and Licensing Models in the Wireless World' (2018) 47 *Research Policy* 1367.

only imperfectly. Consequently, technological capability cannot be reduced to legal access to intellectual property.

This observation resonates with longstanding scholarship in innovation economics. Technological knowledge is neither entirely codified nor fully transferable. As Nelson and Winter famously argued, firms accumulate routines and organizational capabilities that cannot easily be replicated by competitors.¹⁵ Similarly, Polanyi's classic distinction between explicit and tacit knowledge remains highly relevant to contemporary digital value chain and AI ecosystems.¹⁶ While explicit knowledge can be codified in patents, publications, or software repositories, tacit knowledge resides in engineers, research teams, organizational cultures, and production practices. It is acquired through learning-by-doing rather than through access to legal documentation alone.

The limits of open source become particularly apparent in this context. Open-source licensing effectively removes legal restrictions on accessing and modifying software, but it does not eliminate economic, organizational, or technical barriers. Successfully deploying and maintaining sophisticated digital ecosystems requires computational infrastructure, skilled personnel, cybersecurity expertise, continuous maintenance, and institutional capacity. Access to source code is therefore only one component of technological capability. Without complementary investments in human capital and institutional development, open-source technologies may reduce licensing costs without substantially reducing dependency.

Recent developments in generative AI illustrate this point. The release of increasingly open foundation models has undoubtedly democratized experimentation and accelerated scientific research. Nevertheless, the ability to train, fine-tune, and deploy these models at scale remains concentrated among actors possessing access to advanced computing infrastructure, high-quality datasets, specialized engineering talent, and substantial financial resources.¹⁷ Open models have broadened participation, but they have not fundamentally altered the concentration of compute resources or cloud infrastructure upon which advanced AI development depends.¹⁸

This should not be interpreted as a criticism of open source itself. On the contrary, open-source software remains one of the most effective mechanisms for fostering interoperability, cumulative innovation, transparency, and technological diffusion. Over the past three decades, it has profoundly transformed software development and enabled

¹⁵ Richard R Nelson and Sidney G Winter, *An Evolutionary Theory of Economic Change* (Harvard University Press 1982)

¹⁶ Michael Polanyi, *The Tacit Dimension* (Routledge & Kegan Paul 1966).

¹⁷ See Rishi Bommasani and others (n 12); David Gray Widder and others (n 12).

¹⁸ See Belli (n 1); Belli and others (n 1).

countries and organizations to reduce dependence on proprietary vendors. Linux, Kubernetes, PostgreSQL, PyTorch, and countless other projects have become essential building blocks of the global digital infrastructure precisely because they enable collaborative innovation across institutional and national boundaries.

The lesson, however, is that open source is an enabling condition rather than a sufficient condition for digital sovereignty. Openness does not automatically translate into technological agency. On the contrary, the decisive question remains whether actors possess the complementary capabilities required to exercise meaningful control over technology throughout its lifecycle. This includes the ability to audit, modify, integrate, secure, govern, and ultimately innovate upon open technologies according to local priorities and public objectives.

Accordingly, digital sovereignty should not be understood as a legal status derived from ownership of IP or access to open-source code. Rather, it should be conceived as the outcome of an ecosystem of complementary capabilities. IP reform may reduce artificial barriers to innovation, while open-source ecosystems can expand participation and interoperability. Yet neither addresses the deeper structural determinants of technological power, namely control over production capabilities, specialized knowledge, industrial infrastructure, organizational learning, and strategic coordination.

This broader perspective aligns with the conception of digital sovereignty advanced throughout this work. We posit that sovereignty is not achieved simply by replacing proprietary software with open-source alternatives, nor by accumulating domestic IP portfolios. Instead, it emerges from the interaction of governance, regulation, industrial policy, and capacity building that collectively enable actors to acquire, retain, and continuously develop technological capabilities. Open source should therefore be understood as one important instrument within a much wider strategy, which recognizes that the most enduring forms of dependency are often rooted not in law, but in the unequal distribution of knowledge, productive capacity, and institutional competence.¹⁹

2. Strategic Use of Intellectual Property Rights and Open Source

As mentioned above, IPRs function as legal exclusion mechanisms that confer a right to exclude others from using, reproducing, or modifying technological artefacts. Particularly, within the AI ecosystem, IPR operate across multiple layers of the technology stack. These include proprietary datasets protected by trade secrets or contractual restrictions; model architectures and software protected by copyright and licensing arrangements; semiconductor designs and manufacturing processes safeguarded

¹⁹ Ibid.

through patents and trade secrets; proprietary development environments, middleware, and toolchains; and cloud platforms and deployment services that reinforce control through proprietary APIs, licensing terms, and contractual conditions. Collectively, these legal and technical mechanisms enable firms to retain control over key AI assets and create barriers to entry for competitors.

These rights not only generate revenue for incumbents but also systematically constrain the capacity of other actors, such as governments, civil society, research institutions, to adapt, govern, or regulate technology in alignment with sovereign policy goals. The cumulative effect is the creation of structural dependencies that entrench a small set of actors at core layers of the AI stack. In this perspective, this section describes how, similarly to open source IPRs may play a dual role in building digital sovereignty. Indeed, when applied strategically, IPRs may participate in creating systems that reinforce control by some actors, but may also foster systems that dilute control and allow new entrants into technology markets. This dual potential of IPRs is part of a global historical context of intensifying role of intangible assets in the world economy and new forms of value production brought about, principally, by information and communication technologies and digital services and tools.

The current form of the global IPR regime is the result of long-reaching political processes that coalesced in one important global treaty, the World Trade Organisation’s (WTO) Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS Agreement). As a result of the shifting of political debate from the World Intellectual Property Organisation (WIPO) to the WTO, also signalling a shift of IPRs to be subjected to trade interests, signatory States were required to adhere to the TRIPS Agreement, which established minimum IPR terms and regulations to be enacted in participating countries via national legislation.²⁰ These terms defined patentable matter, which meant an expansion of their scope in comparison to existing legislation in some countries, and patent protection periods, which meant an expansion of the time awarded by some countries’ legislation; among other prescriptions concerning copyright, trademarks, and trade secret.²¹

²⁰ Peter Drahos and John Braithwaite, *Information Feudalism: Who Owns the Knowledge Economy?* (Earthscan 2002); Susan K Sell, *Private Power, Public Law: The Globalization of Intellectual Property Rights* (Cambridge University Press 2003).

²¹ Fabienne Orsi and Benjamin Coriat, ‘The New Role and Status of Intellectual Property Rights in Contemporary Capitalism’ (2006) 10 *Competition & Change* 162 <https://doi.org/10.1179/102452906X104222>; Benjamin Coriat and Olivier Weinstein, ‘Intellectual Property Right Regimes, Firms and the Commodification of Knowledge’ (2009) SSRN Electronic Journal <https://doi.org/10.2139/ssrn.1440866>; Peter K Yu, ‘TRIPS and Its Discontents’ (2006) 10 *Marquette Intellectual Property Review* 370.

Through political struggle by low- and middle-income countries (LMICs), grace periods were guaranteed for less industrialised economies, under the recognition that IPRs have a restrictive effect on the formation of endogenous industrial and technological capacities.²² Other exceptions to the protection of IPRs in the signatory countries, also conquered through LMIC efforts, included the capacity to interpret specification of TRIPS terms according to national interests and the possibility of compulsory licensing of patented technologies under certain conditions.²³

The global standardisation of IPRs in this fashion was one of the necessary conditions to allow for a growing role of intangible assets in the world economy, alongside transformations in the managerial structure of the firm and in globalised flows of finance.²⁴ These facilitated exchange in intangibles among economic actors worldwide, particularly that part of scientific and technical knowledge that can be codified. It also served to fixate power relations between advanced-industrialised countries and otherwise, as IPR protection limits diffusion and imitation, which are necessary, albeit not sufficient, conditions for endogenous innovation. Overall, the globalised IPR regime contributed to the “assetization” of knowledge and technology, accelerating the tendency for intangibles to become strategic assets in firms’ portfolios – in other words, knowledge and technology became marketable and tradeable and became part of the valuation of firms in an increasingly financialised global economy.²⁵ This was compounded by forum shifting via bilateral agreements that pushed for TRIPS-plus measures, that is, obligations that went over and beyond what TRIPS demanded, especially impacting LMICs in bilateral negotiations and potentially gravely impacting their strategic positioning²⁶.

This is the backdrop against which strategic use of IPRs is herein analysed. The following subsections will cover the role of IPRs as a mechanism of control, how open source has come about and its relation to IPRs, and how a strategic view of IPRs may reveal paths to overcome the tendency of reinforcing control of technological markets.

2.1. Intellectual Property and Intellectual Monopolies

IPRs evolved to have appropriability of innovative investments by firms as one of their core justifications, that is, the need to ensure recoverability of firms’ spending in producing a certain innovative product or service. This presupposes or depends heavily

²² Carlos M Correa, *Trade Related Aspects of Intellectual Property Rights: A Commentary on the TRIPS Agreement* (Oxford University Press 2007).

²³ Yu (n 1).

²⁴ Drahos and Braithwaite (n 19); Sell (n 19).

²⁵ Orsi and Coriat (n 1); Cecilia Rikap, *Capitalism, Power and Innovation: Intellectual Monopoly Capitalism Uncovered* (Routledge 2021).

²⁶ Susan K Sell, ‘TRIPS Was Never Enough: Vertical Forum Shifting, FTAs, ACTA, and TPP’ (2010) 18 *Journal of Intellectual Property Law* 447.

on assumptions that innovation is mainly conducted or paid for by the innovative firm, that its cost can be precisely determined as pertaining to one definite and linear project, and that a legal right of exclusion of competitors is a necessary and efficient option, in terms of overall societal wellbeing, to recovering those investments. All these assumptions may be legitimately questioned, and especially when faced with the mode of value production and appropriation by the biggest global firms in software and hardware markets. They are, however, bases of justification of the current global regime of IPRs, which has been to a certain degree standardised in various jurisdictions through the effects of TRIPS and deepened in some cases via free trade agreements and investment treaties.²⁷

Thus, when faced with the question of how to assert sovereignty on digital technologies, IPRs play a relevant role, since they are, in essence, means of trading knowledge as assets, and, on the other hand, of ensuring that certain useful social goods are publicized. This is an important aspect of the trade-off that also sits at the basis of IPRs: they aim to stimulate innovators and creators to make their works public, to describe or publish them. In the case of patents, this is made evident in patent application documents, which describe (or should describe) its intended object sufficiently that others might be able to reproduce it. Consequently, they make public what could have been kept secret through trade secret and similar protections.²⁸

In fact, trade secret is a protected category under IPR regulation and is often invoked to maintain secrecy of certain aspects of business operation that have commercial value due to their secrecy. This dynamic is illustrated by companies such as Myriad Genetics and Google, which have used trade secret law to protect proprietary datasets, analytical methods, and data-driven technologies, thereby maintaining competitive advantages beyond the scope of conventional patent protection.²⁹

Although IP law is founded upon a bargain in which disclosure of inventions and creative works is exchanged for exclusive rights of limited duration, maintaining this balance remains inherently challenging.. IPRs are essentially instruments of restriction of the circulation of knowledge. Their value lies specifically in the capacity of one actor, through the coercive power of the State, to exert authority over others regarding the object of the IPRs. Thus, they operate under a logic of restriction and authorisation and, therefore, assertion of control.

²⁷ William W Fisher III, ‘Theories of Intellectual Property’ in Stephen R Munzer (ed), *New Essays in the Legal and Political Theory of Property* (Cambridge University Press 2001).

²⁸ Fisher (n 4).

²⁹ Tantratian Attamongkol, ‘Promoting the Transparency of AI-Generated Inferences’ in Luca Belli and Walter B Gaspar (eds), *The Quest for AI Sovereignty, Transparency and Accountability* (FGV Direito Rio 2023).

Hence, we can argue that the current mode of production in technology-based markets is essentially based in control over the circulation of knowledge, data and other intangible assets.³⁰ Various tools contribute to this capacity of control, as well as various strategies employed by firms. IPRs are one of the main strategic elements of these strategies of control that can be characterised as “intellectual monopolies”³¹. As discussed by Rikap and colleagues, over time, a set of large technology-based firms was able to structure “corporate innovation systems” (CIS) under their control, which serve to organise innovation processes and capture most of the value derived from innovation. In these systems, an intellectual monopoly (IM) agent is able to restrict diffusion and imitation, essential elements to developing absorptive capacity, and to raise entry barriers to contestants. In this fashion, an IM is better positioned to extract rents from the innovation process in perpetuity, as novelty brought about by innovation is under its control.³²

This ability to control innovation processes under a corporate innovation system can be enacted by the IM through various means. It is made evident in partnerships with academic institutions, where the IM publishes alongside researchers, but patents are often under sole titularity of the IM (see Table 1 below); in providing funding for research activities in technological areas of interest, where the IM sets agenda and goals; in hiring of specialised personnel to fulfil strategic research and development goals, and, thus, abandon competing research interests, ensuring control over tacit knowledge incorporated into professionals; in platformization that contain intrinsic feedback, thus locking-in users and developers in their CIS; in acquisitions of innovative firms, either to implement their innovations as part of their portfolios or, more frequently³³, to bury new and competing products and services; in trade secret over databases and algorithms used; and, finally, in these companies’ extensive patent portfolios in most cutting-edge technological fronts.³⁴

³⁰ Baker, Jayadev and Stiglitz (n 4).

³¹ Cecilia Rikap, ‘Intellectual Monopolies as a New Pattern of Innovation and Technological Regime’ (2024) 33 *Industrial and Corporate Change* 1037 <https://doi.org/10.1093/icc/dtad077>; Juan Carlos Miguel de Bustos and Jessica Izquierdo-Castillo, ‘¿Quién controlará la Comunicación? El impacto de los GAFAM sobre las industrias mediáticas en el entorno de la economía digital’ (2019) 74 *Revista Latina de Comunicación Social* 803 <https://doi.org/10.4185/RLCS-2019-1358>.

³² Rikap, ‘Intellectual Monopolies as a New Pattern of Innovation and Technological Regime’ (n 8); Cecilia Rikap and Bengt-Åke Lundvall, *The Digital Innovation Race: Conceptualizing the Emerging New World Order* (Springer International Publishing 2021) <https://doi.org/10.1007/978-3-030-89443-6>; Cecilia Rikap and Bengt-Åke Lundvall, ‘Big Tech, Knowledge Predation and the Implications for Development’ (2022) 12 *Innovation and Development* 389 <https://doi.org/10.1080/2157930X.2020.1855825>.

³³ Axel Gautier and Joe Lamesch, ‘Mergers in the Digital Economy’ (2021) 54 *Information Economics and Policy* 100890 <https://doi.org/10.1016/j.infoecopol.2020.100890>.

³⁴ Rikap, ‘Intellectual Monopolies as a New Pattern of Innovation and Technological Regime’ (n 8); Cecilia Rikap, ‘Dynamics of Corporate Governance Beyond Ownership in AI’ (Common Wealth, 15 May 2024) <https://www.common-wealth.org/publications/dynamics-of-corporate-governance-beyond-ownership-in-ai> accessed 5 October 2024..

Table 1. Selected tech giants’ publications and patents, co-authorships and co-ownerships

COMPANY	PUBLICATIONS (UNTIL 2019 INCLUDED)	CO-AUTHORING ORGANIZATIONS	APPLIED AND GRANTED PATENTS (UNTIL 2017 INCLUDED)	CO-OWNED PATENTS WITH OTHER ORGANIZATIONS
AMAZON	824	766	10,063	13 (0.1%)
MICROSOFT	17,405	4025	76,109	160 (0.2%)
GOOGLE	6447	3397	25,538	65 (0.3%)
TENCENT	643	366	5462	13 (0.2%)
ALIBABA	685	427	3532	0 (0%)

Source: reproduced from Rikap and Lundvall (2021, p. 50)³⁵; Web of science and Derwent innovation (this database includes all the information from the following patent offices: USPTO, WIPO, European, Japan, Australian, British, Canadian, French, German, Russian and Korean patent offices).

In essence, IM’s strategies involve creating and controlling various innovation networks, composed of different organisations, such as research institutions and start-ups, and predating knowledge created within them, with IPRs playing a relevant role in this objective. This is showcased in increasing numbers of patenting activity in frontier-knowledge areas, as well as acquisitions of nascent companies controlling technological innovations in various areas. As such, IMs aim to secure their capacity to extract rent via intangible assets through control of current and future market and technological trends³⁶.

2.2. Open-Source’s relation to IP Rights

The networks that make up an IM’s structure of control over intangibles frequently contain open access of commons arrangements of property. This may seem antithetical, since commons and open access approaches have come out of efforts to organize production in competing manners to the traditional proprietary and market-based mode of production. However, since open access – and, particularly in software, open-source software (OSS) and free and open-source software (FOSS) – strategies develop within existing market-based production, they are intrinsically related to the workings of

³⁵ Rikap and Lundvall (n 9) 50.

³⁶ Gautier and Lamesch (n 10); Bustos and Izquierdo-Castillo (n 8); Rikap, Capitalism, Power and Innovation (n 3); Ioannis Lianos, ‘Digitalisation and Competition Law: New Challenges’ (2019) 7 Revista de Direito da Concorrência..

proprietary schemes. In fact, “free and open source software is dialectically situated between capital and the commons”³⁷, illustrating a close and complex relationship between proprietary software firms and open source initiatives. Linux is a prime example, with firms such as IBM, Samsung, Google, Oracle and Microsoft sitting among the main contributors to development of the Linux Kernel annually³⁸.

Open source is based in general open licensing, a legal solution to the issue of openly and broadly communicating authorisations of use of IP to the public. As such, it does not exist outside of IPRs, but within it: it necessitates a working IPR system to have any meaning. Indeed, when a publisher of a software declares that it grants a “worldwide, royalty-free, non-exclusive, sublicensable license”³⁹ to reproduce, adapt, translate, distribute, perform and display an original work protected by copyright, this declaration only has any meaning within a system of copyright that is able to ensure observance of these licensing conditions.

In the same way, “open” or commons-based development schemes, such as open science networks where data and results are shared, also heavily depend on functioning IPR systems to operationalise the legality of intangibles produced and shared. Although its spirit may be of free flow, it depends, to a varying degree, on existing legal protections to maintain trust between participants and to shield results from early appropriation by outsiders. Importantly, OSS’s potential as a digital public good, removing licensing costs and vendor lock-in, is demonstrated in various instances, but depends on governance arrangements and on the capacity of nations to absorb and adapt open technologies⁴⁰.

Open source, however, covers a much wider scope than a licensing scheme, which merely represents its legal manifestation. It can be described and observed from an institutional perspective – in terms of its formal and informal norms that conform production of open source technical artifacts and organisation patterns⁴¹ –, a form of coordination and production whereby loosely networked individuals are able to

³⁷ Benjamin J Birkinbine, *Incorporating the Digital Commons: Corporate Involvement in Free and Open Source Software* (University of Westminster Press 2020) 3 <https://doi.org/10.16997/book39>.

³⁸ The Linux Foundation, *Who Writes Linux 2016* (The Linux Foundation 2016) https://www.linuxfoundation.org/hubfs/lf_pub_whowriteslinux2016.pdf.

³⁹ ‘Academic Free License v 3.0’ (Open Source Initiative) <https://opensource.org/license/afl-3-0> accessed 23 March 2026.

⁴⁰ Sundeep Sahay, ‘Free and Open Source Software as Global Public Goods? What Are the Distortions and How Do We Address Them?’ (2019) 85 *The Electronic Journal of Information Systems in Developing Countries* e12080 <https://doi.org/10.1002/isd2.12080>.

⁴¹ Charles M Schweik and Robert English, ‘Tragedy of the FOSS Commons? Investigating the Institutional Designs of Free/Libre and Open Source Software Projects’ (2007) 12(2) *First Monday* <https://doi.org/10.5210/fm.v12i2.1619>.

collaborate toward common goals in often non-market intermediated arrangements⁴² and even as a political and social movement based on a “concrete utopia” and incorporated into “critical discourse, singular practices and an alternative social ideation”⁴³.

Additionally, OSS’s impact over the economy as a whole is reiterated in literature, with global value creation estimated at roughly USD 8.8 trillion⁴⁴; a contribution of between EUR 65 and 95 billion specifically related to EU GDP, a cost-benefit ratio above 1:4 and an additional 0.4–0.6% of GDP annually from a projected 10% increase in open source contributions⁴⁵; and significant positive effects over startup growth and national competitiveness in observed cases.⁴⁶

2.3. Thinking systemically about IPRs and open source, towards strategic modularity

Based on our previous considerations, it is important to acknowledge that open-source strategies are applied by large firms as a complement to, rather than a replacement for, their proprietary strategies. An often-utilised example is pharmaceutical companies’ participation and organising role in open access arrangements, to profit from other institutions’ – universities, research institutes, start-ups – intellectual labour.⁴⁷ Similarly, in the digital technology sector, participation in OSS ecosystems can reinforce the IM dynamics in several ways. It provides firms with access to reusable code that can be incorporated into subsequent innovations; valuable technical and commercial knowledge generated by smaller firms and independent developers; insights into user needs and emerging markets, as OSS communities often constitute an important source of future customers and commercial opportunities; and the benefits of community-driven labor,

⁴² Yochai Benkler, *The Wealth of Networks: How Social Production Transforms Markets and Freedom* (Yale University Press 2007) https://cyber.harvard.edu/wealth_of_networks/Main_Page#Read_the_book accessed 6 July 2026.

⁴³ Sébastien Broca, *Utopie du Logiciel Libre: Du bricolage informatique à la réinvention sociale* (Le Passager clandestin 2013) <https://fr.scribd.com/document/684704576/Se-bastien-Broca-Utopie-du-logiciel-libre-Du-bricolage-informatique-a-la-re-invention-sociale-Le-passager-clandestin-2013> accessed 6 July 2026.

⁴⁴ Manuel Hoffmann, Frank Nagle and Yanuo Zhou, ‘The Value of Open Source Software’ (Harvard Business School Strategy Unit Working Paper No 24-038, 2024) <https://doi.org/10.2139/ssrn.4693148>.

⁴⁵ Knut Blind and others, ‘The Impact of Open Source Software and Hardware on Technological Independence, Competitiveness and Innovation in the EU Economy: Final Study Report’ (European Commission Directorate General for Communications Networks, Content and Technology Publications Office 2021) <https://doi.org/10.2759/430161>.

⁴⁶ Frank Nagle, ‘Government Technology Policy, Social Value, and National Competitiveness’ (2019) <https://doi.org/10.2139/ssrn.3355486>; Nataliya Wright, Frank Nagle and Shane Greenstein, ‘Contributing to Growth? The Role of Open Source Software for Global Startups’ (2024) <https://doi.org/10.2139/ssrn.4699182>.

⁴⁷ Alexander Schuhmacher and others, ‘Open Innovation: A Paradigm Shift in Pharma R&D?’ (2022) 27 *Drug Discovery Today* 2395.

whereby developers voluntarily review, debug, fork, and extend software that firms may subsequently incorporate into proprietary products or services⁴⁸.

The innovation management literature theorises these dynamics as techniques of value capture in open innovation⁴⁹, and identifies specific mechanisms through which firms appropriate value created by open-source environments, carefully balancing open source and IPR to assert their private digital sovereignty. Selective revealing discloses components where community co-development is advantageous while withholding those that ensure a firm’s competitive advantage. Mobilisation of complementary assets such as distribution, brand, installed user base, and cloud infrastructure and compute, a firm may capture value from an open-sourced innovation layer⁵⁰.

A recent and compelling example of open source being deployed as a market strategy to reshape value capture can be seen in both Meta and Nvidia’s enthusiastic support for open-source AI.⁵¹ Meta’s backing of open-weight release families (such as Llama and Muse Glimmer) serves as a classic strategy to commoditize its complements.⁵² By offering the capital-intensive foundation model layer for free, Meta relocates strategic control, value capture, and monetization up to the user engagement and advertising layer, an ecosystem where it already holds a dominant market position. For Nvidia, promoting open models is highly strategic move to shift value extraction down the tech stack to where true scarcity resides: semiconductors, hardware infrastructure and compute. Additionally, openness at the model layer diverts revenue away from closed-model creators like OpenAI, Google, and Anthropic, thus reducing their financial capacity to develop proprietary in-house chips and break reliance on Nvidia hardware. Finally, yet importantly, IP modularity aligns the technical architecture of a system with its IP structure, allowing the firm to maintain open collaboration over portions of a modular system while maintaining proprietary appropriation over other portions⁵³.

Empirical studies of firm participation on GitHub confirm a pattern of selective firm participation. Firms concentrate contributions unevenly and lead different projects, with a

⁴⁸ Rikap, *Capitalism, Power and Innovation* (n 3) 55–56.

⁴⁹ Henry Chesbrough, Christopher Lettl and Thomas Ritter, ‘Value Creation and Value Capture in Open Innovation’ (2018) 35 *Journal of Product Innovation Management* 930 <https://doi.org/10.1111/jpim.12471>.

⁵⁰ Joachim Henkel, ‘Selective Revealing in Open Innovation Processes: The Case of Embedded Linux’ (2006) 35 *Research Policy* 953 <https://doi.org/10.1016/j.respol.2006.04.010>; David J Teece, ‘Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy’ (1986) 15 *Research Policy* 285 [https://doi.org/10.1016/0048-7333\(86\)90027-2](https://doi.org/10.1016/0048-7333(86)90027-2)

⁵¹ ‘NVIDIA Open Source’ (NVIDIA) <https://opensource.nvidia.com/en-us/> accessed 18 August 2026;

‘Open Source AI’ (Meta AI) <https://ai.meta.com/opensourceai/> accessed 18 August 2026.

⁵² Joel Spolsky, ‘Strategy Letter V: Commoditize Your Complement’ (Joel on Software, 12 June 2002) <https://www.joelonsoftware.com/2002/06/12/strategy-letter-v/>.

⁵³ Joachim Henkel, Carliss Y Baldwin and Willy Shih, ‘IP Modularity: Profiting from Innovation by Aligning Product Architecture with Intellectual Property’ (2013) 55 *California Management Review* 212.

minority of firms accounting for most commits, and a minority of projects attracting their collaboration. Meanwhile, the labour of unpaid volunteers remains significant and, unlike that of firm employees, stays constant across time⁵⁴. These are not neutral efficiencies but the means by which intellectual monopolies predate on collectively and externally produced knowledge.

Open source and commons-based arrangements have, however, produced competing dynamics to that of intellectual monopolies. It produced one the major and longer-running operating systems currently in use worldwide, Linux; one of the top five web browsers in use since 2002, Firefox; the most popular web-builder software in use since 2003, WordPress; and major technological autonomy strategies for countries worldwide. Generally, free and open-source software is used due to its lower cost and higher security, the latter due to its network-based distributed software development, testing and debugging dynamics.⁵⁵

Hence, OSS generates knowledge spillovers that are in principle universally accessible, but empirically benefit actors with the strongest complementary assets disproportionately. OSS indeed contributes positively to competitiveness and technological independence, but the gains are unevenly distributed across firm size and national capability levels.⁵⁶ OSS generates social value and national competitiveness gains, but the translation from open contribution to captured value depends on pre-existing absorptive capacity and infrastructure⁵⁷. OSS diffuses software power broadly but incumbent platform firms, overwhelmingly US-based, leverage complementary assets (cloud, data, distribution) to appropriate disproportionate strategic returns⁵⁸. The first policy implication is that governments cannot treat OSS adoption as inherently equalizing. Indeed, the question must always be who controls the adjacent proprietary layers. Hence, leveraging open source for the purposes of building one’s digital sovereignty requires a profound strategic understanding of ownership across the whole technological stack. It also means governments should reject the open-vs-closed binary in favour of a strategic and instrumental mobilization of OSS.

⁵⁴ Mathieu O’Neil and others, ‘The Coproduction of Open Source Software by Volunteers and Big Tech Firms’ (DCPC & News and Media Research Centre 2021) <https://doi.org/10.25916/R8VG-HD09>.

⁵⁵ Tuesday Bwalya, Akakandelwa Akakandelwa and Milena Dobрева-McPherson, ‘Adoption and Use of Free and Open Source Software (FOSS) Globally: An Overview and Analysis of Selected Countries’ (2019) Library & Information Science Research; ‘WordPress Market Share, Statistics, and More’ (WordPress.com News, 17 April 2025) <https://wordpress.com/blog/2025/04/17/wordpress-market-share/> accessed 27 March 2026; StatCounter, ‘Internet Browser Market Share 2012–2025’ (Statista, 19 November 2025) <https://www.statista.com/statistics/268254/market-share-of-internet-browsers-worldwide-since-2009/> accessed 27 March 2026.

⁵⁶Blind and others (n 45).

⁵⁷ Nagle (n 46).

⁵⁸ Pannier (n 8).

The ubiquitous adoption of OSS has created a “sovereign digital chain” problem: sovereignty is not located in a single technology choice but distributed across a stack of interdependent layers, each requiring distinct yet interconnected governance decisions⁵⁹. OSS has formed an intertwined technological stack that functions as shared global infrastructure: a foundation no actor fully controls and from which no actor can fully exit⁶⁰. OSS communities and standard-setting organizations operate through horizontal, non-hierarchical coordination mechanisms that states must understand and engage with selectively rather than wholesale⁶¹. The implication is a modular sovereignty strategy, aimed at identifying which layers of the stack are strategically critical (where proprietary control or domestic capability matters) versus which can safely rely on shared OSS infrastructure.

Hence, what becomes critical from a digital sovereignty perspective is the capacity to participate in the governance of the OSS stack, or the capacity to audit, fork, contribute, and govern one's position within a shared system rather than to own it outright. The auditability of open code is central to this as it enables trust and cooperative governance across actors who do not share political alignment, which partially dissolves the zero-sum framing of technological competition. However, shared foundations create structured dependencies that generate power asymmetries. The policy conclusion that follows is not simply “adopt more OSS” but rather: map the stack, identify dependency risks at each layer, invest in domestic contribution capacity at strategically critical nodes, and engage OSS governance institutions as a form of standards diplomacy.

3. Public Policies to Strategically Mobilize Open Source for Digital Sovereignty

As the preceding sections have shown, digital sovereignty is not a monolithic capacity but a composite of regulatory power, infrastructural independence, and technical capability. In this perspective, open technologies change the terms of sovereignty competition. By creating shared infrastructure that any party can inspect, fork, and maintain, they reduce the stakes of bilateral dependencies. Rather than a zero-sum choice between autarky and full dependency, participation in open technological systems can

⁵⁹ Gaël Duval, ‘From Sovereign Operating Systems to the Sovereign Digital Chain’ in Giuseppe Primiero and Liesbeth De Mol (eds), *Reflections on Programming Systems, Historical and Philosophical Aspects* (Springer Cham 2018) https://doi.org/10.1007/978-3-319-97226-8_9. See particularly Belli (n 1).

⁶⁰ Marco Berlinguer, ‘Digital Commons as New Infrastructure’ (2022) 11 *Umanistica Digitale* 5 <https://doi.org/10.6092/ISSN.2532-8816/13695>.

⁶¹ Mirko Boehm and Eisape Davis, ‘Standard Setting Organizations and Open Source Communities: Partners or Competitors?’ [2021] *First Monday* <https://doi.org/10.5210/fm.v26i7.10806>.

generate mutual benefits that spill over beyond the participating countries themselves, a dynamic some describe as “interdependent autonomy”⁶².

These benefits are widely recognized, but they are not equally distributed. In a global context, asymmetries reflect structural conditions that predate the digital economy and are reproduced within it. So-called Global Majority countries – i.e. former colonized countries which are now emerging economies and, largely, very low, low or middle income countries – operate within international technology regimes shaped by colonial and imperial legacies: regimes in which IPRs remain heavily concentrated in the Global North, digital labor is systematically undervalued and outsourced, data generated in the South is extracted and monetized elsewhere, and the material costs of digital infrastructure (from mining to e-waste) are disproportionately borne by peripheral economies.⁶³ Open technologies do not dissolve these structures. A country may have irrevocable legal access to a codebase while lacking the engineers, institutions, energy infrastructure, and fiscal space to do anything with it. Not all countries benefit in the same way from participation in open technological systems, nor do they enter these systems with the same capacities. This raises a central question: under what conditions, and through which strategies, can countries, including lower-income countries, mobilize open technologies to meet their own strategic needs?

Building on maturity models developed for the management of open-source ecosystems in organizations,⁶⁴ this section proposes a progressive comparative framework applied at the country level, from access to capability and trajectory-shaping⁶⁵. Section 3.1 examines the defensive use of open source to secure access and hedge against economic lock-in and political control through IPRs. Section 3.2 examines capability-building and industrial policy strategies that build on participation in open technologies. Section 3.3 examines the deployment of open technologies as an instrument of standard-setting and technological trajectory-shaping.

⁶² Mirko Boehm, ‘How Open Source Coordinates: A Guide for Policy Makers – Understanding Horizontal Governance in the FOSS Ecosystem’ (Geneva Dialogue, 28 January 2026) <https://genevadiologue.ch/how-open-source-coordinates-a-guide-for-policy-makers/>.

⁶³ Michael Kwet, ‘Digital Colonialism: US Empire and the New Imperialism in the Global South’ (2019) 60(4) *Race & Class* 3 <https://doi.org/10.1177/0306396818823172>; Ulises A Mejias and Nick Couldry, *Data Grab: The New Colonialism of Big Tech and How to Fight Back* (University of Chicago Press 2024) <https://press.uchicago.edu/ucp/books/book/chicago/D/bo216184200.html>.

⁶⁴ TO DO Group, ‘OSPO Landscape – OSPO Five-Stage Maturity Model’ (Linux Foundation 2021) <https://landscape.todogroup.org/guide#ospo-five-stage-maturity-model>.

⁶⁵ These three stages are analytical rather than strictly sequential. In practice, capability-building and trajectory-shaping can proceed in parallel, and countries may engage in standard-setting in one domain while remaining dependent consumers in others. The progression is heuristic: it maps the conditions under which each form of leverage becomes available, not a development ladder that must be climbed in order.

3.1. Securing access – Open technologies as a shield against economic dependencies and political control in Brazil

The defensive adoption of open alternatives to proprietary technologies has historically relied on three arguments that address three vulnerabilities of proprietary technologies. The first is economic lock-in: proprietary licensing enables vendors to extract recurring rents from users, whose ability to switch to competing technologies becomes progressively constrained by accumulated switching costs, technological dependence, and vendor lock-in⁶⁶. The second relates to cybersecurity: closed source code cannot be independently audited, making it impossible for governments to verify what their own infrastructure does, whether it contains backdoors, or whether it transmits data to third parties⁶⁷. The third, and most recently weaponized, is geopolitical: access to digital infrastructure and intellectual property can be revoked through export controls and sanctions, as demonstrated by the ZTE and Huawei cases from 2018 onward and the subsequent exposure of critical dependencies in software toolchains, cloud services, and development environments⁶⁸. The diffusion of open technologies, in contrast, is very hard to prevent, especially once software has been published under open licenses that are irrevocable⁶⁹.

Open technologies have been considered to address all three vulnerabilities simultaneously. They eliminate recurring licensing fees; they make code available for independent security inspection; and, crucially, they provide a legally irrevocable guarantee of continued access. For these reasons, OSS adoption, particularly in the public sector, was already being framed as a defensive strategy in the early 2000s. This first global wave of public sector OSS policies, spanning Asia, Europe, and Latin America, was primarily driven by procurement cost savings and vendor lock-in concerns⁷⁰. The case of Brazil, where the government actively promoted OSS adoption during this period,

⁶⁶ Björn Lundell, Jonas Gamalielsson and Simon Butler and others, 'Enabling OSS Usage Through Procurement Projects: How Can Lock-in Effects Be Avoided?' in Davide Taibi and others (eds), *Open Source Systems* (Springer International Publishing 2021) https://doi.org/10.1007/978-3-030-75251-4_2.

⁶⁷ Andrew Meneely and Laurie Williams, 'Secure Open Source Collaboration: An Empirical Study of Linus' Law' (16th ACM Conference on Computer and Communications Security, November 2009) 453 <https://doi.org/10.1145/1653662.1653717>.

⁶⁸ Henry Farrell and Abraham L Newman, 'Weaponized Interdependence: How Global Economic Networks Shape State Coercion' (2019) 44(1) *International Security* 42 https://doi.org/10.1162/isec_a_00351.

⁶⁹ Benjamin Jean, 'Open Source and Export Control in 2026' (Inno³, 29 April 2026) <https://inno3.fr/en/blog/open-and-controlled-open-source-export-control-2026/>.

⁷⁰ Blind and others (n 45).

provides a rich illustration of both the opportunities and the structural limitations of these policies.⁷¹

Brazil's free software movement emerged in the late 1990s from a convergence of labor activism and Linux adoption within the state technology companies of the southern state of Rio Grande do Sul. In 1999, technical staff at state IT companies founded the *Projeto Software Livre do Rio Grande do Sul* (PSL-RS), which grew rapidly into a national network⁷². When Luiz Inácio Lula da Silva, better known as Lula, was elected president in 2003, this network of what Shaw (2011) calls “insurgent experts” – technically skilled elites embedded simultaneously in public institutions, the Workers' Party of President Lula, and the free software community – was positioned to translate a social movement into federal policy. Within months of the inauguration, a Committee for the Implementation of Software Livre (CISL) produced a strategic plan endorsed by the President, multiple federal agencies began migrating servers and workstations to Linux, and Brazil established the Brazilian Public Software Portal in 2007 as a collaborative repository where government agencies could share and develop software under the GPL. At the subnational level, the states of Rio Grande do Sul, Paraná, and Santa Catarina passed laws establishing a preference for free software in public procurement. Normative Instruction No. 4, adopted in 2010, subsequently required all federal procurement officers to justify any choice of proprietary software over available open-source alternatives⁷³.

The economic rationale was explicit and well-documented. Brazil was spending approximately one billion US dollars on Microsoft licensing fees between 1999 and 2004, with estimates suggesting savings of \$120 million per year were achievable by switching to free software⁷⁴. Paraná state, following the adoption of its preferential free software laws in 2003, reported savings of \$127.3 million in the first three years of implementation⁷⁵. Beyond cost savings, open-source procurement was understood to redirect public expenditure from foreign vendors toward domestic service providers, system integrators, and technical support firms — keeping value within the national economy rather than exporting it as licensing rents. Brazil's choice of the GPL v2 as the

⁷¹ Luca Belli and M Jiang, 'Conclusion: Digital Sovereignty in the BRICS: Structuring Self-Determination, Cybersecurity, and Control' in M Jiang and Luca Belli (eds), *Digital Sovereignty in the BRICS Countries: How the Global South and Emerging Power Alliances Are Reshaping Digital Governance* (Cambridge University Press 2025) 214.

⁷² Aaron Shaw, 'Insurgent Expertise: The Politics of Free/Livre and Open Source Software in Brazil' (2011) 8(3) *Journal of Information Technology & Politics* 253 <https://doi.org/10.1080/19331681.2011.592063>.

⁷³ Benjamin Birkinbine, 'Free Software as Public Service in Brazil: An Assessment of Activism, Policy, and Technology' (2016) 10 *International Journal of Communication* 16; Marcella Furtado De Magalhães Gomes, Roberto Vasconcelos Novaes and Mariana Guimarães Becker, 'Open Source Software, Access to Knowledge and Software Licensing' (2015) *Human Rights Rule of Law and the Contemporary Social Challenges in Complex Societies* 100 https://doi.org/10.17931/ivr2013_sws24_02.

⁷⁴ Birkinbine (n 71).

⁷⁵ Furtado De Magalhães Gomes, Novaes and Becker (n 71).

official government license was deliberate in this respect: the GPL's copyleft mechanism ensures that publicly funded software cannot be appropriated by a private contractor and returned to the government as a proprietary product, functioning as a legal lock against the re-enclosure of public digital infrastructure.

The security argument was present from the outset, and in some respects preceded the economic one. Brazilian intelligence services and the armed forces were among the early institutional adopters of Linux, driven specifically by the need to audit the code running on sensitive infrastructure, a concern about foreign surveillance that preceded the Snowden revelations by more than a decade ⁷⁶. After 2013, these concerns intensified: President Dilma Rousseff's public denunciation at the United Nations of US digital surveillance, and Brazil's subsequent push for an Internet Bill of Rights and a sovereign digital infrastructure, drew directly on the logic that proprietary software running on foreign-controlled platforms was incompatible with genuine political autonomy ⁷⁷. The security dimension of OSS adoption thus operated at two levels: at the technical level, auditability reduces the risk of backdoors and undisclosed data transmission; at the political level, open licensing combined with domestically hosted infrastructure reduces exposure to the kind of platform governance decisions that can sever access unilaterally.

Despite the ambition of these policies, their practical impact was significantly constrained by the absence of a capable domestic ecosystem to translate access rights into operational independence. In other words Brazil failed to leverage OSS to become digitally sovereign as it only considered it from the adoption perspective, rather than the development perspective. A longitudinal survey of free software use across Brazilian states conducted in 2023 and 2024 found that while 22 of 26 states regularly deploy open-source tools, only one had actually produced software meeting the Free Software Foundation's definition of free software and most governments remained pure consumers, with no evidence of contribution to upstream communities⁷⁸. A case study of SERPRO, the federal data processing company that served as the institutional flagship of the movement, found that of more than 800 projects the company classified as open source over fifteen years, only four genuinely met the relevant criteria, as the remainder lacked either publicly available source code or a free license ⁷⁹. The fragility of the institutional arrangements was equally apparent: when the political entrepreneurs who had embedded the agenda within the bureaucracy departed, the formal policy architecture persisted but

⁷⁶ Shaw (n 70).

⁷⁷ Birkinbine (n 71).

⁷⁸ Flávio Gomes da Silva Lisboa, ‘Use and Production of FLOSS in Brazilian States: An Wider Survey’ (Anais do XXI Congresso Latino-Americano de Software Livre e Tecnologias Abertas (Latinoware 2024), 27 November 2024) 315 <https://doi.org/10.5753/latinoware.2024.245338>.

⁷⁹ Flávio Lisboa and Marilene Beatriz, *Um Recorte Da História Do Software Livre No Estado Brasileiro: Um Estudo De Caso Do Programa De Software Livre Do Serpro* (6 December 2019).

lost its animating force and, as of 2016, the Digital Governance Policy did not even mention open source.

The Brazilian experience encapsulates a tension that recurs across defensive open-source strategies: open licenses create genuine legal leverage, and in moments of geopolitical disruption – such as export control shocks, platform exclusions, surveillance revelations – this leverage can be critical. Access to technology that cannot be legally revoked is a meaningful sovereignty asset. But securing access is not the same as securing capability. A policy focused solely on adoption relocates rather than resolves dependency: the code is legally available to fork and maintain, but doing so requires engineers, institutions, procurement capacity, and sustained political will.

Where these conditions are absent and there is no domestic ecosystem capable of providing alternatives to proprietary vendors, and no institutional continuity that survives changes in political coalition, the open license remains a dormant option rather than an exercised capacity, and wealth transfers persist under new forms (software of infrastructure as a service, technical consultancy, etc.). The transition from access to genuine capability is the subject of the following section.

3.2. Learning by doing – The Korean model of open technologies as education and industrial policy tools

Open technologies trace their origins to the science and teaching ethos that shaped early computing culture, where the sharing of code, methods, and results was understood as constitutive of the research enterprise rather than incidental to it ⁸⁰. The open science movement has extended this logic across the research cycle, and studies of frontier innovation consistently find that openness correlates with faster knowledge diffusion, higher rates of recombination, and broader participation in cutting-edge development.⁸¹

What distinguishes open technologies from other forms of technology transfer, however, is not merely free access but the conditions they create for learning by doing: the ability to read, modify, test, and contribute to real production systems, embedded within communities of practice that transmit tacit knowledge alongside formal documentation.⁸²

⁸⁰ Christopher M Kelty, *Two Bits: The Cultural Significance of Free Software* (Duke University Press 2008) <https://doi.org/10.2307/j.ctv1198vx9>; Andrew L Russell, *Open Standards and the Digital Age: History, Ideology, and Networks* (1st edn, Cambridge University Press 2014) <https://doi.org/10.1017/cbo9781139856553>.

⁸¹ Fiona Murray and others, ‘Of Mice and Academics: Examining the Effect of Openness on Innovation’ (National Bureau of Economic Research 2009) <https://doi.org/10.3386/w14819>.

⁸² Fiona Murray, Philippe Aghion, Mathias Dewatripont, Julian Kolev and Scott Stern, ‘Of Mice and Academics: Examining the Effect of Openness on Innovation’ (NBER Working Paper No 14819, 2009) <https://doi.org/10.3386/w14819>.

Unlike classical intellectual property transfer arrangements, which involve complex, costly negotiations and barriers that systematically disadvantage low-income economies, open licenses reduce transaction costs to near zero and extend participation rights irrevocably to any actor willing to engage.⁸³ Governments can therefore build on global commons without starting from scratch, developing local expertise through participation while contributing improvements that serve national interests.⁸⁴

The mere existence of the open source option does not mean that a thriving and sustainable open source ecosystem can be easily established, but the consideration of the governance aspects of it can transform Open source in a powerful instrument of domestic capability building. The most compelling illustrations of this potential have emerged in Asia, notably in China, Japan and South Korea, where OSS has long been integrated into workforce development strategies alongside industrial policy.⁸⁵ South Korea offers one of the most instructive cases, with two decades of policy engagement with open technologies. South Korea's engagement with open-source software can't, however, be understood apart from its broader tradition of state-directed industrial transformation. From the 1960s onward, the Korean developmental state used targeted policy instruments – such as coordinated procurement, protected domestic markets, directed credit, and mandatory technology transfer requirements – to propel successive waves of industrial upgrading, from steel and shipbuilding through semiconductors, consumer electronics, and telecommunications. By the time Samsung had established itself as a global leader in memory chips and LG in consumer electronics, Korea had demonstrated a consistent capacity to absorb foreign technology, build domestic competence around it, and eventually compete at the frontier.

The Korea Linux Council, founded in 1999, was a direct expression of this same logic applied to software: a state-adjacent coordination body bringing together government research centers, industry, and universities to orient domestic actors toward open source as a strategic technology domain, well before any geopolitical crisis made the urgency explicit.⁸⁶ The “1-24 Computer Disaster” of January 2003, when the Slammer virus exploited a Microsoft vulnerability and crippled Korean internet infrastructure more severely than any other country radicalized movements supporting policy intervention for open source, converting a background industrial policy concern into an acute political

⁸³ Benkler (n 42).

⁸⁴ Nagle (n 46).

⁸⁵ Nir Kshetri and Andreea Schiopu, 'Government Policy, Continental Collaboration and the Diffusion of Open Source Software in China, Japan, and South Korea' (2007) 8(1) *Journal of Asia-Pacific Business* 61 https://doi.org/10.1300/J098v08n01_06.

⁸⁶ Kwang-Suk Lee, 'From Underground Cult to Public Policy for Citizens: Democratizing an Open Source Artifact at a Policy Level in South Korea' (2006) 8(1) *Info 4* <https://doi.org/10.1108/14636690610643249>.

priority.⁸⁷ The government's subsequent commitment to replace Microsoft systems across government institutions, the reconstitution of the Korea Linux Council as the Korea Open Source Software Association in 2006, the 2014 Open Source Software Invigoration Plan, and the 2020 Software Promotion Act amendment mandating open disclosure of publicly funded R&D outputs all followed the same developmental template: identify a strategic technology, build an institutional architecture around it, anchor the domestic ecosystem through public procurement, and graduate from dependency toward competitive capacity.⁸⁸ OSS policy was, in this sense, the software chapter of a much longer industrial policy story.

The human capacity effects of this policy architecture were substantial and deliberately engineered. The OSS World Challenge, launched in 2006 by the National IT Industry Promotion Agency (NIPA), exposed participants across two divisions –school students and the general public – to the full OSS development lifecycle, from project planning and implementation through to license verification, and by 2012 had attracted four hundred domestic teams alongside eighty-three international teams from thirty-three countries.⁸⁹ Its deliberate internationalization after 2008 was a pedagogical choice: Korean developers needed exposure to global peers and standards that domestic competition alone could not provide. In parallel, the Open-Source Software Learning Community Centre established a professional training portal combining curated courses with a community-generated curriculum, reaching fifteen thousand members and over eleven hundred lectures by 2008.⁹⁰ The later OSS Contribution Academy, housed within the Open Up center founded in 2020 by integrating previously separate support institutions, made the critical pedagogical shift explicit: its purpose was not to train consumers of open source but contributors to it, supporting Korean developers to participate in and improve upstream global projects.⁹¹

The industrial and ecosystem effects extended these individual gains into structural changes in Korea's position within the global software economy, following a pattern recognizable from earlier Korean industrial policy cycles. Government procurement anchored commercial viability during the formative period, the early bulk purchase of Hancom Linux and Hancom Office products created guaranteed domestic demand for

⁸⁷ Lee (n 84); Kshetri and Schioppa (n 83).

⁸⁸ Vivien Devenyi, Debora Di Giacomo and Corinna Vetter, Open Source Software Country Intelligence Report South Korea (Open Source Observatory (OSOR), European Commission 2021) <URL>; Hanna Shmagun, Jangsup Shim, Kwang-Nam Choi, Suk Kyung Shin, Jaesoo Kim and Charles Oppenheim, ‘Korea’s National Approach to Open Science: Present and Possible Future’ (2024) 50(3) Journal of Information Science 766 <https://doi.org/10.1177/01655515221107336>.

⁸⁹ NIPA (National IT Industry Promotion Agency), Open Source Software White Paper (Ministry of Knowledge Economy 2012) <https://kossa.kr/materials/homepage/공개소프트웨어백서2012.pdf>.

⁹⁰ NIPA (n 87).

⁹¹ Devenyi, Di Giacomo and Vetter (n 86).

firms that might otherwise have been unable to compete against established proprietary vendors, mirroring the protected home market strategies that had incubated Korean competitiveness in electronics and semiconductors.⁹² Within the trilateral CJK open-source alliance coordinated with China and Japan, Korea was assigned development of software and applications for mobile devices, aligning OSS strategy directly with its existing industrial strengths in consumer electronics and telecommunications.⁹³

The Asianux project, a joint venture among Korea's Haansoft, China's Red Flag Software, and Japan's Miracle Linux, produced a standardized regional Linux distribution running on over fifty thousand business servers across the three countries by early 2006, a concrete market output demonstrating that OSS policy was generating industrial results rather than merely policy commitments.⁹⁴ Korean firms simultaneously deployed domestically cultivated OSS capacity as an export instrument, with LG shipping Linux-loaded PCs to India and Hancom developing Arabic-language Linux distributions for Middle Eastern markets, converting domestic capability into international commercial advantage in precisely the manner Korean industrial policy had engineered in earlier technology sectors.⁹⁵ The 2019 OSS R&D program completed this arc by embedding open-source participation into the national innovation system itself, requiring major research institutes and companies to develop and distribute open-source R&D results.⁹⁶

The Korean experience supports several conclusions that extend beyond the national case. Open licenses are a necessary but insufficient condition for capability building: irrevocable access to code creates an option, but exercising that option requires engineers, institutions, and sustained political will. The transition from consuming open source to co-developing it does not occur spontaneously and requires deliberate institutional investment, as Korea's successive support programs illustrate. The most durable capability gains emerge when OSS policy is integrated into broader industrial strategy rather than administered as a standalone procurement preference, because it is the connection between open-source skills, domestic firms, export markets, and public R&D that converts individual competence into ecosystem strength.

Finally, sustained co-development generates returns that extend beyond technical capacity: active participation in open-source communities produces influence over their governance, over the standards they establish, the architectures they adopt, and the technological directions they pursue. Capability built through learning by doing becomes,

⁹² Kshetri and Schioppa (n 83).

⁹³ *Ibid.*

⁹⁴ *Ibid.*

⁹⁵ *Ibid.*

⁹⁶ Devenyi, Di Giacomo and Vetter (n 86).

at sufficient scale and depth, a form of structural power in global technological development. That dynamic is the subject of the following section.

3.3. Shaping developments – The Indian use of open technologies as a source of standard-setting power

The preceding sections have traced a progression from defensive access to active capability building. Both stages, however, remain largely reactive: they allow actors to participate in technological systems whose trajectories are shaped elsewhere. The most consequential use of open technologies is neither defensive nor imitative but constitutive: the deliberate use of openness to shape the standards, architectures, and directions of technological development that others will later follow. This third stage has attracted growing attention in the political economy of technology. Berlinguer argues that strategic actors use openness not as an alternative to market power but as a tool for creating and reshaping markets.⁹⁷ Open-source software has become an explicitly geopolitical instrument, with major powers using openness to shape standards, govern ecosystems, and extend institutional influence.⁹⁸

For Global Majority countries, the strategic logic is similar but more difficult to implement. It requires prior investments in capabilities, while the institutions that determine which architectures become standards remain concentrated in a small number of countries. India provides a particularly revealing example of how open technologies can be used not only to build domestic capabilities but also to shape technological trajectories beyond national borders. For decades, India occupied a paradoxical position in the global digital economy. Despite having a large pool of highly skilled engineers, it struggled to move beyond its role as a provider of low-cost IT services for Western firms. The country accumulated technical expertise but captured relatively little value from the technologies it helped develop, remaining dependent on standards, platforms, and architectures largely defined elsewhere.⁹⁹

The emergence of Digital India, India's digital transformation strategy and, particularly, its Digital Public Infrastructure (DPI) approach can be understood as an attempt to overcome this position.¹⁰⁰ The “India Stack”, including Aadhaar, the Unified Payments Interface (UPI), and the Account Aggregator framework, emerged from a coalition

⁹⁷ Marco Berlinguer, ‘Commons, Markets and Public Policy: Experiments at the Frontier of Technological Revolution’ (European Network for Alternative Thinking and Political Dialogue 2020) <https://transform-network.net/publication/commons-markets-and-public-policy/>.

⁹⁸ Pannier (n 8).

⁹⁹ Dwaipayan Banerjee, *Computing in the Age of Decolonization: India's Lost Technological Revolution* (Princeton University Press 2026).

¹⁰⁰ Luca Belli and Larissa Galdino de Magalhães Santos (eds), *SmartBRICS: How the BRICS Countries are Regulating their Digital Transformation* (Springer 2025).

between the Indian developmental state and domestic software entrepreneurs. The objective was to create a domestic digital market through shared infrastructure capable of supporting large-scale digital services. A key feature of this strategy was the decision to build the stack around open protocols together with interoperable and modular components. This architecture allowed private firms to develop commercial services on top of publicly funded infrastructure, effectively socializing the costs of core digital systems while enabling value creation at the application layer.¹⁰¹

Openness therefore functioned not simply as a principle of accessibility but as a mechanism for market creation based on national standards for identity, payments, and data exchange.¹⁰² The openness of these components also created another strategic advantage: solutions initially developed for domestic use became exportable. Because they were modular, relatively low cost, and adaptable to different institutional settings, they could be adopted by countries facing similar development challenges.¹⁰³ This transformed DPI from a tool of domestic state building into a source of international influence.

The diffusion of these architectures expanded opportunities for Indian firms, consultants, and technical experts, while increasing the visibility and legitimacy of the standards embedded in the Indian model. India has actively supported this internationalization through a combination of technical openness, diplomatic engagement, and institution building. Skillfully taking advantage of its G20 chairmanship, India promoted initiatives such as the G20 Global DPI Repository, partnerships with multilateral organizations, and support from philanthropic actors including the Gates Foundation have helped present DPI as a global public good rather than a national technology export. The language of openness, interoperability, and inclusion has been central to this effort, presenting Indian-developed solutions as attractive alternatives.¹⁰⁴

¹⁰¹ Derryl D'Silva, Zuzana Filková, Frank Packer and Siddharth Tiwari, *The Design of Digital Financial Infrastructure: Lessons from India* (BIS Papers No 106, Bank for International Settlements 2019); Mila T Samdub, 'The State and Software Capital' *Phenomenal World* (16 October 2025) <https://phenomenalworld.org/analysis/digital-india/>.

¹⁰² Luca Belli, 'Building Good Digital Sovereignty Through Digital Public Infrastructures and Digital Commons in India and Brazil' (SSRN Scholarly Paper No 4966348, 11 September 2024) <https://doi.org/10.2139/ssrn.4966348>.

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¹⁰⁴ Rudra Chaudhuri, 'Decoding the G20 Consensus on Digital Public Infrastructure: A Key Outcome of India's Presidency' (Carnegie Endowment for International Peace, 1 September 2023) <https://carnegieendowment.org/research/2023/09/decoding-the-g20-consensus-on-digital-public-infrastructure-a-key-outcome-of-indias-presidency>. Arindrajit Basu, 'What India's Push for Global Digital Repositories Tells Us About Its Tech Diplomacy' *TechPolicy.Press* (6 March 2026) <https://www.techpolicy.press/what-indias-push-for-global-digital-repositories-tells-us-about-its-tech-diplomacy/>.

The case of MOSIP (Modular Open Source Identity Platform) illustrates this strategy particularly well. Developed from the experience of Aadhaar, MOSIP provides a modular open source digital identity platform that countries can adapt to their own needs. Hosted by the International Institute of Information Technology Bangalore and supported by a coalition of governments, international organizations, and philanthropic funders, MOSIP has been adopted across Africa, Asia, and other regions. Rather than remaining under direct state control, the platform is presented as shared digital infrastructure that countries can customize and govern locally.¹⁰⁵

Yet MOSIP does more than export software: it exports a particular vision of digital governance shaping digital transformation processes well beyond Indian borders. The design choices that emerged from the political economy of the state-iSPIRT coalition travel with the architecture. The centralized biometric identity model, the emphasis on scalability and financial inclusion over privacy by design, and the limited role of civil society in governance are not implementation failures but defining features of the system itself.¹⁰⁶ Countries that adopt MOSIP also inherit a particular philosophy of digital identity, one that may be difficult to challenge or modify once administrative systems are built around it.

Hence, through the diffusion of open standards, governance frameworks, and technical architectures, India has actively shaped international discussions about the scope and purpose of digital public infrastructure. The Indian case illustrates a distinctive form of trajectory-shaping power available to countries outside the traditional centers of technological dominance. By combining domestic capability building with open and modular infrastructure, and by embedding these technologies within diplomatic and multilateral initiatives, India has transformed solutions developed for national challenges into globally circulating standards. In doing so, it has not only created new opportunities for its firms and institutions but has also extended the reach of the vision on which its DPI strategy was originally built.

4. Conclusion

The analysis developed throughout this chapter reinforces a central conclusion: digital sovereignty cannot be reduced to the legal availability of technologies or to the adoption of open-source solutions. Rather, it emerges from the interaction between legal regimes,

¹⁰⁵ Eugenia Lostri, Georgia Wood and Meghan Jain, 'Government Open Source Software Policies' (Center for Strategic and International Studies) <https://www.csis.org/programs/strategic-technologies-program/resources/government-open-source-software-policies>.

¹⁰⁶ Reetika Khera, 'Aadhaar Failures: A Tragedy of Errors' (2019) 54 Economic and Political Weekly <https://www.epw.in/engage/article/aadhaar-failures-food-services-welfare>.

technical capabilities, institutional capacities, and strategic governance across the different layers of the digital stack. Open technologies can substantially expand the range of strategic options available to states, firms, and communities by lowering barriers to access, fostering collaboration, and reducing exclusionary dependencies. Yet openness alone neither redistributes power nor guarantees autonomy. Its capacity to foster sovereignty ultimately depends on the ability to mobilize complementary assets, including engineering expertise, computing infrastructure, industrial capabilities, sustainable financing, and governance institutions

The case studies further demonstrate that open source should not be understood as the opposite of IP, but as one institutional arrangement operating within broader IPRs. Open-source licensing simultaneously enables collaboration and constitutes a mechanism for shaping technological standards, coordinating innovation, and influencing market structures. At the same time IPRs and trade secrets continue to determine access to critical assets such as proprietary datasets, tacit knowledge, semiconductor technologies, cloud infrastructure, and advanced model development pipelines. Sovereignty therefore depends not on the wholesale replacement of proprietary regimes by open ones, admitting that such scenario might even be possible, but on strategically managing the complementarities and tensions between openness, exclusivity, and secrecy across the AI ecosystem.

This perspective also highlights that digital infrastructures are not monolithic systems but layered socio-technical assemblages, each characterized by distinct forms of dependency, governance, and concentration of power. Consequently, countries may achieve considerable autonomy in some layers while remaining structurally dependent in others. Effective techno-regulatory strategies therefore require a systemic understanding of cross-layer dependencies, the identification of strategic bottlenecks, and targeted interventions where public investment, industrial policy, legal reform, or participation in open ecosystems can generate the greatest leverage.

Strategically leveraging openness to build digital sovereignty requires a deep understanding of this layered structure, the interdependencies between layers, the actors operating within them, and the specific conditions needed to foster openness, whether to disrupt competitors or to gain market leverage. Translating this strategic vision into practice is far from trivial, as evidenced by the fact that large technology corporations, rather than nation-states, have historically been the most successful at implementing it. Nevertheless, as the preceding examples demonstrate, it is feasible for governments to formulate and strategically execute a coherent vision of digital sovereignty across these interconnected layers.

In this context, it is important to stress that digital sovereignty is necessarily purposive. Open technologies are regulatory and technological instruments rather than ends in themselves. Their strategic value depends on the objectives they are intended to advance. Defining these objectives is therefore a prerequisite for selecting the appropriate combination of open-source strategies, IP policies, trade secret protections, and capacity-building measures.

Especially for Global Majority countries, the pursuit of digital sovereignty requires a long-term, ecosystemic approach that combines openness with sustained investment in institutions, skills, industrial capabilities, and international cooperation. Only by integrating these complementary dimensions can open technologies contribute not merely to greater access to digital infrastructures, but to a meaningful redistribution of power, wealth and developmental capacities.