DECODING DIGITAL PUBLIC INFRASTRUCTURE

SCRIPTING INCLUSIVE DIGITAL FUTURES

SRINIVASAN R • PRANJAL SHARMA • ANIRBAN SARMA

Editors

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Srinivasan R, Anirban Sarma, and Pranjal Sharma

Crossing Borders

Speaking at the AI Action Summit in Paris in February 2025, Prime Minister Narendra Modi declared, “India has successfully built a digital public infrastructure (DPI) for over 1.4 billion people at a very low cost. It is built around an open and accessible network. It has regulations, and a wide range of applications to modernise our economy, reform governance and transform the lives of our people.”[1]

Indeed, DPIs and related digital goods and services have proven their potential for driving digital inclusion, boosting service delivery and innovation, and ensuring digital human rights without compromising on trust and security. Encouraged by the scale of success, several other states in the Global South have begun to build their DPIs with India’s support.

The enthusiasm around DPIs goes well beyond the South. The European Union is working with India to make their respective DPIs more interoperable, and

the two have "pledged to promote DPI solutions to third countries."[2] Similarly, the United States (US) has made a commitment with India to enter into a Global Digital Development Partnership to pool technology and resources and help build DPIs in developing nations.[3] The Group of 20 (G20) too, has actively been promoting the exploration and uptake of DPI since the Indian presidency of 2023, through the Brazilian presidency of 2024, and the ongoing presidency of South Africa during which the G20 aims to create possible instruments to support DPI implementation as well as guidelines for DPI governance.[4]

Digital Public Infrastructure and Digital Public Goods

DPIs refer to "a set of shared digital systems which are secure and interoperable, built on open standards, and specifications to deliver and provide equitable access to public and private services at societal scale, and are governed by enabling rules to drive development, inclusion, innovation, trust, and competition, and to respect human rights and fundamental freedoms."[5]

They adhere to the basic principles of *public* infrastructure, i.e. they are indivisible, non-exclusionary, and offer opportunities for public value capture.[a] Leading examples of DPIs in India include the Aadhaar unique digital identity; the Unified Payments Interface (UPI)—a real-time payments system; and the Data Empowerment and Protection Architecture (DEPA)—a secure consent-based data-sharing framework. These and other DPIs have been instrumental in shaping India's digital economy, in much the same way that physical infrastructure like roads or ports have contributed to its economic growth and development.

DPIs are composed of building blocks such as software code, platforms, applications and application programming interfaces (APIs) that are interoperable and generic. Because these blocks are modular in nature, they can be combined to create a stack of technologies that constitute the DPI's architecture.

The term 'digital public goods' (DPGs), while sometimes incorrectly used interchangeably with DPIs, is a distinct yet complementary concept. DPGs are defined as "open-source software, open data, open artificial intelligence models, open standards and open content that adhere to privacy and other applicable best practices, and do no

a 'Indivisibility' refers to the efficient organisation of different components of a system in a way that they provide undifferentiated value to its agents/users, and the value of the system as a whole is much greater than its individual components. The principle of being 'non-exclusionary' refers to the provision of free and open access in a non-discriminatory manner to all agents/users. 'Public value capture' refers to the quality of infrastructure to provide a range of positive externalities to agents/users and society at large, with or without the creation of private value.

harm."[6] Some of them are part of the building blocks that help operationalise DPIs, as the preceding paragraph indicates, but they are not DPIs themselves. DPGs and digital public services are typically citizen-facing and provide specific value propositions for end users.

The DPG Alliance requires that a "good DPG" should fulfil nine conditions. These include being relevant to the Sustainable Development Goals (SDGs), using approved open licenses, being independent of any particular platform, having mechanisms for extracting data, and conforming to applicable privacy and security laws and standards.[7] Bhashini, India's AI-led language translation platform,[8] and Co-WIN, the Covid-19 Vaccine Intelligence Network, which allowed citizen registration, record-keeping and certificate generation during the country's whole-of-population vaccination drive,[9] are both important examples of Indian DPGs.

The Indian Approach

India's approach to DPI implementation differs from the routes to digitalisation adopted by other big economies.[10] In some countries, private technology platforms have created 'walled gardens' of tech infrastructure, algorithms, and services. These large platforms typically operate in—and dominate—winner-takes-all markets. At the other end of the spectrum are certain states that are driven primarily by government-tech: governments take end-to-end responsibility for selecting technologies, building infrastructures, and providing products and services.

The Indian DPI approach lies midway between these two extremes. Here, the government and regulators have provided the basic techno-legal framework and undergirding, and the digital infrastructure is provisioned according to a public-private partnership model.[11] In such a system, there are market incentives for the private sector to invest in and innovate around products, service development, and user engagement. This ensures a synergistic balance between government investments in technology, the private provisioning of public infrastructure, and the need for citizen-centricity in implementation.

A metaphor often used to describe the functioning of DPIs is that of a digital railroad. At its foundation is the *infrastructure layer* laid by the government (which is akin to a railway track), upon which the DPI's *building blocks* are placed (much like signalling systems and traffic management algorithms). Atop these two layers run the *consumer applications* and services developed by the private and public sectors (i.e. the trains in the metaphor).

The impact of DPI in India has been extraordinary, and it is measurable in both quantitative and qualitative terms. The speed and scale of its implementation—foundational DPIs now cover virtually the country's entire population—have been especially widely lauded. There is little doubt that the strategic expansion of DPI will be central to India's growth, and to the national aspiration of becoming a US$8-trillion economy by 2030.[12]

The figures demonstrating DPI's growth and impact are impressive by any standard. In 2022, DPI's contribution to India's gross domestic product (GDP) was 0.9 percent, and this is projected to increase to 2.9-4.2 percent by 2030.[13] 1.3 billion Indian citizens or 96.8 percent of the population have Aadhaar digital IDs, and some 99.9 percent of all Indian adults use the Aadhaar ID to avail of a service at least once every month. Seeding Aadhaar with bank accounts and payment systems has been instrumental in enabling a dramatic increase in the number of bank accounts. In 2011, only 15 percent of the Indian population above 15 years of age had bank accounts, but this increased to 77.5 percent in 2022.[14]

UPI enabled 70 percent of all digital payment transactions in India in FY 2023-24, and acted as a key driver of financial inclusion and digital payments, processing some 16.6 billion transactions by October 2024.[15] India's DigiLocker has provided digital space access to 32 million users, and the 3.69 billion documents stored so far are facilitating efficient paperless governance.[16] And e-NAM (National Agriculture Marketplace) has provided services to 16.4 million farmers while integrating 585 agricultural marketplaces, and allowing transactions worth INR 700 billion.[17]

DPIs have also resulted in the establishment of domain-specific open stakeholder networks. India's Open Network for Digital Commerce (ONDC) is democratising e-commerce by bringing businesses and small merchants on to a common platform for buying and selling goods and services. As of January 2024, the ONDC operated across more than 616 Indian cities, propelling the growth of e-commerce.[18] Similarly, the Open Credit Enablement Network (OCEN) pilot is beginning to transform the country's credit landscape by supporting interactions between lenders and account aggregators, and ensuring a smoother flow of credit to small businesses and entrepreneurs.[19]

Future Considerations

With the passage of the Digital Personal Data Protection (DPDP) Act in August 2023, after years of deliberations, India now has a data protection law in place. The enforcement of the Act is yet to begin, however, and the Rules that will guide its implementation are currently being finalised.[20] In the meantime, public and private entities that deal with personal data are working to make themselves DPDP-compliant.

Going forward, the potential friction between DPI and the DPDP Act will need to be negotiated. As legal experts observe, "With Aadhaar providing a foundational digital ID and UPI supporting billions of monthly transactions, DPI has enabled seamless, inclusive access to essential services. However, the scale of these systems has amplified regulatory challenges. The DPDP Act, which mandates data protection and privacy standards, adds additional regulatory requirements for compliance. Striking a balance between accessibility and compliance with these privacy protections is now critical."[21]

For instance, India's National Health Authority has integrated the DPI model into its Ayushman Bharat Digital Health Mission (ABDHM) to create an interoperable digital health ecosystem. This national health stack includes digital health IDs and electronic health records, and enables patient-provider interactions to advance access to quality healthcare. Given the sensitivity of health data, however, stringent compliance with the DPDP Act will be crucial, especially around the receipt of explicit consent for collecting and processing personal data. Similarly, in the transport sector, the National Highway Authority of India's FASTag system allows for efficient cashless toll payments, and has reduced operational costs and congestion across highways. Under the DPDP regime though, FASTag will have to meet substantial data localisation and privacy requirements. These will increase as it finds new use cases such as parking and fuel payments.[22]

India's three foundational DPIs—digital identity, a payments interface, and a data-sharing architecture—are well established, but pathways for creating a greater number of foundational DPGs could be explored. Today, Aadhaar acts as a tool that validates one's identity, but it may also be productive to reimagine identity as a DPG that allows one to check-in at a hotel or other facilities. This is conceptually different from the use of the DigiYatra app at airports, which provides a form of digi-attendance. The idea of digi-checkins would involve capturing images and proof of government IDs, collecting electronic signatures, and encrypting and securely storing this data.[23]

The notion of location as a DPG is already being explored through a pilot titled DHRUVA (Digital Hub for Reference and Unique Virtual Address). Executed by India's Department of Posts, it aims to build a "digital address DPI" that will "allow users to create, access, share, manage and use their address information." DHRUVA will "support the traditional addressing system by enabling users to depict and share their addresses in a standardised and geo-coded format," and is expected to "enhance address precision, reduce errors in communication and service delivery."[24]

The DHRUVA ecosystem consists of two main layers: the DIGIPIN (Digital Postal Index Number), which is a ten-digit alphanumeric code that uniquely identifies locations using geospatial data; and a 'Digital Address' built upon the DIGIPIN that will allow users to self-generate unique labels to represent their DIGIPIN and their descriptive address(es). In many ways, this is akin to people's UPI IDs, which dispense with the need to rewrite one's bank account details each time one needs to make a payment. As with the foregoing examples of the ABDHM and FASTag however, DHRUVA too, will need to prioritise meeting the DPDP Act's conditions. As the policy document governing its development emphasises, there must be "strong safeguards to ensure the privacy and security of the information shared" and the system must be "compliant with applicable laws such as the Digital Personal Data Protection Act, 2023."[25]

Additionally, strengthening the foundational layers of digital infrastructure is essential to enable the sustainable growth and scaling of DPIs. This includes expanding telecommunication connectivity through wider coverage and affordable access, alongside other core enablers. It is also important to enhance the robustness of existing DPI platforms. Identity systems like Aadhaar can be made more robust by preventing duplicate registrations and the elimination of ghost identities. These foundational improvements are critical to ensure the reliability, inclusiveness, and long-term viability of India's digital ecosystem.

The Present Publication

This publication was inspired by a day-long stakeholder engagement event co-hosted by the Observer Research Foundation (ORF) and the Indian Institute of Management Bangalore (IIMB) at the IIMB campus in August 2024. Titled "Decoding DPI: Scripting Inclusive Digital Futures", the event brought together experts, practitioners, and institutions who are helping shape India's DPI ecosystem, and technology thinkers and researchers in the domain.

The event focused on three themes: the key principles that ought to be kept in mind when designing and rolling out DPIs; the private provisioning of public infrastructure; and the implications of DPI for innovation and competition. The three main chapters of this volume address these themes, and for each of them, the authors have taken key issues identified during the discussions and supplemented them with further research and analysis.

Chapter 2, 'The DPI Principles Guiding India's Digital Ascent', by Manisha Rathi and Anulekha Nandi, unpacks five principles or sutras governing the design of DPIs. They include: ensuring citizen's agency and privacy; promoting interoperability through the

use of open standards and APIs; crafting techno-legal regulation, or combining public technology with law to ensure the ethical use of tech; preventing corporatisation and private monopolies; and safeguarding DPIs against weaponisation.

Chapter 3, 'Private Provisioning of Digital Public Infrastructure', by Pramoth Kumar Joseph and Tanusha Tyagi, examines the concept of privately provisioned public goods, and its relevance and application to DPIs. It investigates instances of private sector participation in DPI implementation that have enhanced DPIs' impact, analyses why such involvement is necessary, and goes on to propose public-private partnership models for developing DPIs that embed a viable profit motive for private actors.

Chapter 4, 'Digital Public Infrastructure: Balancing Innovation and Competition', by Anuradha Sharma and Basu Chandola, explores how DPIs have unleashed innovation and entrepreneurship by allowing enterprises to design novel applications atop the DPI layers. This has galvanised competition and improved consumer experience. But while DPIs' creation of a relatively level playing field for businesses is widely celebrated, the chapter warns that sometimes they could paradoxically foreclose the possibility of competition and produce new monopolies instead.

The publication's concluding chapter, by its editors, brings together the principal findings and recommendations from Chapters 2–4, and points to certain new phenomena, such as the convergence of artificial intelligence (AI) and DPI, that must increasingly be navigated.

As the twenty-first century reaches its quarter-way mark, DPI is entrenching itself in the lives and imaginations of citizens and nations across the world. Not only has it redefined citizen-state-enterprise interactions domestically, it has also positioned India as a digital partner of choice for the Global South and a natural development partner for much of the North. Against this background, the present publication hopes to spark further conversations and debates about DPI's foundational ethos, its evolving architecture, its strengths and weaknesses, and what it could mean for our collective digital futures.

Srinivasan R is Professor of Strategy and Chairperson, Center for Digital Public Goods, IIM Bangalore.

Anirban Sarma is Director, Centre for Digital Societies, ORF.

Pranjal Sharma is Non-Resident Fellow, ORF Middle East, and an economic analyst and author.

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The DPI Principles Guiding India's Digital Ascent

Manisha Rathi and Anulekha Nandi

India offers a highly diverse and expansive landscape, marking itself as a distinct context for scholarly exploration. It is the most populous country in the world, with nearly 1.5 billion people spread across geographical, cultural, and economic cohorts. The country is young, with a median age below 30,[1] and digitally connected, with over 750 million active Internet users.[2,3] Such diversity and scale amplifies the challenges for the country's economic and financial systems. On one hand, India is home to half a million poor people dependent on government assistance in the form of subsidies and welfare programmes; on the other, only 6.68 percent of the population contributes to the tax base.[4] Moreover, much of the aid disbursed to the poor fails to reach the beneficiaries due to leakages in the system.[5]

An ideal remedy would be to reduce the intermediaries and conduct direct transfer benefits (DBTs) instead, but such schemes are effective only if the aid reaches recipients' bank accounts in full. However,

until around a decade or so ago, large portions of India's population remained unbanked, primarily due to the absence of any valid identification documents. The exclusion from the formal banking system not only restricted access to DBTs but also to other banking services such as credit and insurance. It further limited access to government welfare programmes. For instance, individuals without proper identification faced challenges in obtaining ration cards essential for subsidised food and accessing healthcare benefits without valid ID proof.

An important development during the first decade of the 21st century happened in the form of digital penetration. The reduced cost of hardware, coupled with increased Internet access, expanded the digital reach into remote areas of the country. As the rise of digital technology offered new avenues for growth, it also emerged as a source of hope for addressing long-standing challenges. However, research has noted that many digital solutions of the time were developed in Western countries and adapted to emerging economies without accounting for local contexts.[6] Such solutions often failed to align with India's needs and constraints. For example, rural regions often faced limited internet bandwidth and language barriers, making it difficult to implement foreign-developed educational platforms effectively. Digital implementations lacked social embeddedness and transformative potential, and the country needed digital innovations tailored to its landscape. The country needed digital innovations tailored to its landscape to tackle its economic and financial predicament.

The Evolution of India's Digital Public Infrastructure

The foundations of India Stack were laid when visionaries identified three interrelated issues—inefficient government service delivery, lack of financial inclusion, and an India-centric digital innovation deficit. They recognised the need to tailor digital solutions to address India-specific challenges, aiming to ensure social protection by enabling equitable access through digital technology. They embraced Unix's stack approach and Linux's open-source philosophy as dependable ideologies to create a robust and efficient system that could work for the Indian context. The stack started with establishing a verifiable digital identity, enabling real-time financial transactions digitally. Its open architecture created avenues for incremental innovations. All the stack elements together shaped India's revolutionary Digital Public Infrastructure (DPI).

The Foundational DPI: Aadhaar[a]

Figure 1: A Sample Aadhaar Card

Source: https://www.indiastack.global/aadhaar[7]

Launched in 2019 by the Unique Identification Authority of India (UIDAI), Aadhaar has become the world's largest biometric initiative.[b] Trust was critical for its adoption, given concerns about the sharing of personal data and the potential for misuse. Therefore, the system had to incorporate transparency and security as its operating principles, with trust becoming central to its design, which would inform the development of subsequent components of India Stack.

The digital identity provided by Aadhaar has transformed India's socio-economic landscape. The share of the population covered under Aadhar has steadily increased over the years, reaching more than 93 percent by FY 2022-23.[8] The widespread adoption has led to an increase in the number of DBTs. The total number of DBTs linked to Aadhaar-enabled bank accounts increased from 0.07 billion in May 2014 to 10.77 billion in March 2023.[9] Aadhaar-enabled DBTs have also reduced leakages,

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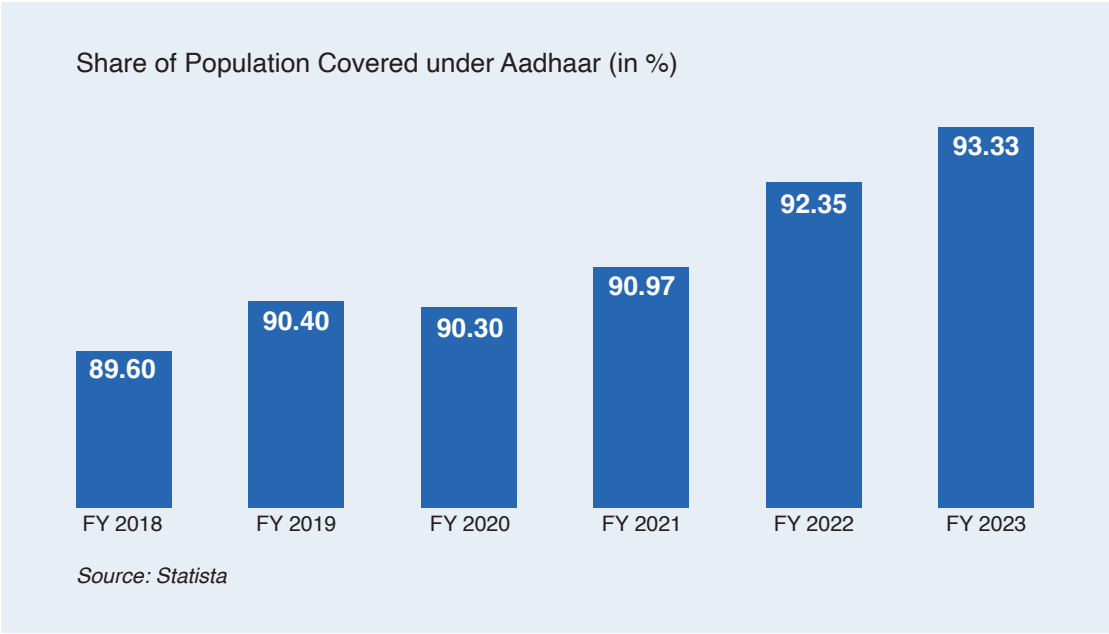
a Aadhaar is a Hindi word meaning 'foundation'.

b In 2009, the UIDAI launched the digital identity system, Aadhaar, marking a seminal moment in India's DPI journey. Aadhaar is a 12-digit identity number assigned to every Indian resident and linked to basic biometric and demographic data. The goal is to enable individuals, especially those without any formal identity documentation, to be able to verify their identity and access government services and benefits. Aadhaar was the first step in fostering inclusivity across socio-economic strata. Since its launch, Aadhaar's scope has expanded beyond social welfare, becoming a crucial tool for digital governance. In recent years, Aadhaar authentication has been mandated for processes such as the filing of tax returns, obtaining electricity/mobile phone connections, as well to fulfil KYC (know your customer) guidelines.

ensuring that subsidies reach beneficiaries directly. For instance, the domestic gas subsidies linked with Aadhaar have saved the government INR 127 billion (approx. US$1.5 billion) by curbing duplicate and fraudulent connections.[10]

Figure 2: Aadhaar Coverage



As the Aadhaar system matured, it evolved into the Modular Open-Source Identity Platform (MOSIP), a more flexible and decentralised iteration that could be adopted by other countries aiming to develop their own digital identity systems. MOSIP is an example of innovation at scale, having incorporated learnings from the Aadhaar journey. Its design is customisable and modular as opposed to Aadhaar's more centralised system. This flexibility in design enables countries adopting MOSIP to customise it according to their contexts and needs, e.g., they can choose between a centralised authentication system or local device storage for data. At the time of writing this article, MOSIP has been adopted by 26 countries,[11] becoming the global standard for digital identity systems.

The Guiding Principles: DPI Sutras[c]

As the idea of DPI gained momentum, its scope and definition became diluted and the term is now used for all forms of government technology, platforms, or open-source systems. Therefore, it is essential to understand the guiding principles that qualify a technological system as a DPI, prioritising inclusivity and the public good.

[c] 'Sutra' is a Sanskrit word referring to a collection of aphorisms.

DPI makers view it as India's gift from which the world could immensely benefit. They believe that the design and development of DPIs is guided by principles that form the foundation of India's ethos. These foundational principles guide the design, implementation, and operation of DPIs to ensure trust, safety, and innovation.[12] They also help distinguish what qualifies as a DPI and what does not. These sutras address key concerns regarding citizen-centricity, interoperability, regulation, market dominance, and weaponisation. The following paragraphs discuss these concerns and the mechanisms within DPI to address them.

Citizen Agency and Privacy

Citizen-centricity is a foundational principle that prioritises citizens' agency and privacy. It empowers them by ensuring their agency over personal data while safeguarding their privacy. It asserts that users should have control over how their data is collected, stored, and used. Citizen-centricity can be ensured through strong data protection laws, such as India's Digital Personal Data Protection Act, 2023 (DPDP Act), or the European Union's General Data Protection Regulation, 2018 (GDPR). Additionally, frameworks like the Data Empowerment and Protection Architecture (DEPA), 2020[13] or executing privacy-preserving techniques like differential privacy also help maintain citizen agency and privacy for DPI to be trustworthy.

Interoperability

A basic requirement for DPI implementation is maintaining a balance of power between the citizens, the state, and the market. It should not be affected by monopolisation and consolidation. This balance ensures that no entity has undue influence or control over others. Inherent interoperability within the DPI is critical to achieving this balance. It warrants that different digital systems can seamlessly interact and exchange information, enabling greater efficiency and inclusivity. For DPI, this means open APIs and interoperable, modular architectures that allow public and private players to interact with little obstacle for efficient service delivery and innovation. This allows users to conveniently migrate between operators, fostering healthy competition and preventing vendor lock-in or market consolidation. India Stack, including Aadhaar and UPI (Unified Payments Interface), exemplifies interoperability by enabling multiple service providers to integrate with government platforms.

The Techno-Legal Regulation

DPIs are structurally technical, but due to their public nature and scale of operation, they require a combination of legal frameworks. A synergistic techno-legal regulatory approach integrates technological solutions with legal oversight to ensure security,

efficiency, and inclusion. For example, the scale of the digital payment DPI, UPI, which on-boards more than 600 banks and sees over 15 million transactions per month,[14] underscores the need for robust regulatory mechanisms to manage such high-volume digital interactions. DPI-related regulations should be adaptive and technology-neutral, ensuring evolution while remaining accountable. These regulations must also include governance mechanisms for grievance redressal, cybercrime mitigation, and algorithmic accountability. Techno-legal regulations establish that DPIs are not only technologically sound but also legally compliant, preventing unintended harm. India's techno-legal DPI design has exemplified trust, privacy, and consent management.

Bypassing Corporatisation and Private Monopoly

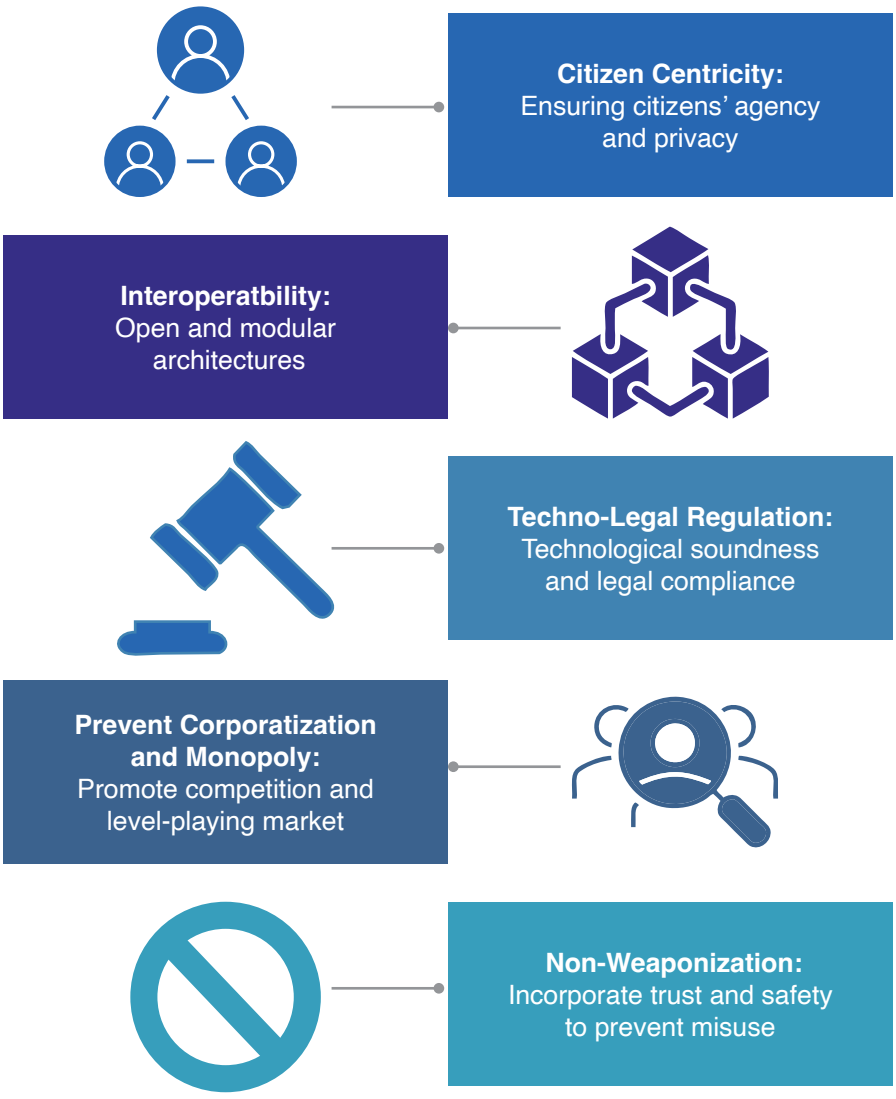
Preventing the monopolisation of digital services by large private corporations is an indispensable characteristic of a DPI. Even as it is a citizen-centric framework, it must also promote competition within the market. The components of India's DPI ecosystem, such as Aadhaar and UPI, demonstrate how public digital infrastructure can challenge private monopolies. Aadhaar-based identity verification allows for e-KYC and reduces the cost accrued from field-based KYC activities, creating a level playing field by lowering entry barriers for small players. It also prevents data monopolisation by decentralising data control. For example, in 2016, when telecom provider Jio used Aadhaar authentication and on-boarded customers in 10 minutes, its subscriber base grew to over 100 million within a week, forcing competitors, who took longer, to follow suit. Likewise, UPI reduced reliance on card-based payment systems, fostering competition among banks and fintech companies. These examples illustrate how DPIs can effectively counter private monopolies, ensuring that essential digital services remain accessible and equitable for all.

Safeguarding Against Weaponisation

All the above guidelines reinforce that the DPIs must incorporate trust and safety by design to prevent their misuse as tools of surveillance, exclusion, coercion, or manipulation. This critical principle requires efforts on multiple fronts, including data handling, governance models, and technical robustness. DPIs must be designed to ensure that personal data is encrypted, anonymised, and accessed only with user consent. For instance, UIDAI employs certain measures to safeguard against the weaponisation of Aadhaar identity, such as storing only the timestamp of Aadhaar-based authentication, without the context where authentication is done. Additionally, it deletes the stored history every six months, ensuring the safety and confidentiality of personally identifiable information.

Open and decentralised governance models can further enhance transparency and reduce misuse by either governments or non-state actors. Strong cybersecurity measures, such as encryption protocols, continuous monitoring, and multi-stakeholder oversight, must be deployed to defend against cyberattacks and digital threats. Additionally, the possibility of weaponisation by foreign actors must be addressed by establishing norms to curb it. Embedding strong legal, technical, and governance frameworks will foster citizen trust, encourage faster adoption, and ensure population-scale benefits.

Figure 3: DPI Sutras



Source: Authors' own

The five DPI sutras endorse that digital infrastructures must serve the public interest, safeguard individual rights, and promote innovation while resisting monopolisation and misuse. While India's DPI journey showcases a model many countries are now looking to adopt to address their core issues, DPI is not a short-lived project that ends with implementation.[15] It is a long-term endeavour that involves constant learning and introspection. Furthermore, it necessitates efforts to comply with principles while ensuring conscience keeping at local levels and encouraging diffusion at global levels.

Conclusion

India has taken a leadership role in positioning DPIs as an accelerator for global development, as highlighted in the G20 New Delhi Leaders' Declaration, 2023[16] under the Indian presidency. DPIs, born out of India's contextual challenges, have led to the development of a solution and template for other countries in the Global South. The evolution of the India Stack shows that DPI can encode guiding principles into its design to achieve socio-economic equity and innovation objectives by connecting the last mile. As India paved the way for the global adoption of DPI approaches in management and regulation, it offers a template for other countries working on building their own DPIs.

As DPIs evolve, their potential extends to addressing systemic inefficiencies and challenges. The next wave of DPI innovation will focus on going beyond inclusion to enhance ease of doing business and simplify regulation. This requires a techno-legal approach that streamlines service delivery and integration by connecting businesses and citizens more efficiently. It is also important to ensure that DPI systems remain accessible and equitable, avoiding domination by any single entity or corporation. Therefore, ensuring trust and security is paramount, achieved through mechanisms that build citizen confidence in the system. Additionally, the roles and responsibilities of each participant must be clearly defined: the government as the service and regulation provider, developers designing the system, businesses innovating on top of it, and 'conscience keepers' who sustain the trust and essence of the DPI.

'Conscience Keeping' and Trust Building

The proliferation, export, and adaptation of DPI have highlighted the need for its design, development, and implementation across contexts to adhere to its guiding principles. In this view, the conscience keepers are the guardians of the guiding principles. Their task is to ensure that these principles are upheld, enabling DPIs to be used responsibly for the greater good. Given the significance and depth of the guiding principles, conscience-keeping for DPIs is a tough task. This cannot be done

by enforcing laws, which can be broken, or by relying on regulations, which can be manipulated. Rather, public technology and public policy need to work together and shape behaviour, ensuring that public technology provides convenience while policy ensures compliance.

Due to their public-centric nature, conscience keepers for DPIs must be public-driven entities. These can be academic research centres, think tanks, or non-profit institutions. The idea is to encourage transparency through conscience keeping, enabling unbiased and impartial, evidence-based investigation of DPI aspects. This also diminishes the chances of the government or DPI component owners acting as conscience keepers, which is crucial in maintaining trust, fairness, and the sustainability of the DPI, considering its massive socio-economic influence.

Trust in digital technology is a key determinant of its adoption and use.[17] The scepticism often found among beneficiaries towards technology may lead to reluctance in accepting it, reducing its effectiveness. For instance, when Aadhaar faced privacy and security concerns during its initial phases, a legal approach was adopted. The regulatory changes made Aadhaar an essential but not mandatory form of identification. DPI beneficiaries must be assured that their personal data is secured and used only with their consent. Trust building requires strong legal, technical, and ethical safeguards. While the open nature of technology enhances transparency, regular auditing, public oversight, and decentralisation can lead to greater trust for the DPI. This is because enforcing laws and regulations may have a limited role in trust building, as laws are not the predictor of behaviour. By prioritising adherence to DPI sutras, DPIs would remain inclusive and resilient. Conscience keepers, therefore, have a crucial role to play in ensuring that DPIs remain trustworthy.

Modularity and Adaptation

DPIs are long-term, evolving digital artifacts opening up avenues for new developments and innovations. Since DPIs serve as the foundation for other components, their modularity and adaptability are crucial. Modularity comes from independent but interoperable components, allowing flexibility and scalability. DPI adaptation suggests their ability to adapt to and evolve with the changing technologies, regulatory revisions, or changes in user requirements. With modularity and interoperability, DPI components can seamlessly integrate at lower costs. In the case of the Indian DPI stack, while the identity, payments, and data exchange layers function separately, they also effortlessly combine with each other to enable ancillary services like DigiLocker—a cloud-based digital document storage system.

Moreover, the interoperable modular blocks facilitate customisation to meet local needs. For example, India's UPI model was adapted in Singapore (PayNow-UPI linkage) without changing its core structure. This modular approach enhances reusability and resilience. Modular DPIs support open APIs, allowing different actors of the system—such as governments, businesses, and developers—to build on existing infrastructure without disrupting core systems. Moreover, modular systems reduce the risk of breakdowns due to a single point of failure. If one component faces any issue, the rest of the system remains operational. Overall, modularity and adaptability are important for the long-term and worldwide effectiveness of DPIs.

Internationalisation

With adaptability, DPIs can be internationalised.[d] Internationalisation causes global interoperability and cross-border innovation. This is exemplified by the case of MOSIP, which was created as a template for other countries after Aadhaar's success. Countries like Sri Lanka, the Philippines, Brazil, and some in the African region have customised and adopted MOSIP for deploying digital identity systems. Countries are also exploring the adoption of real-time payment systems like UPI to promote financial inclusion. At the core of internationalisation lies modularity, which allows customisation for specific needs and purposes. Internationalisation streamlines cross-border trade and commerce, enhances competition, and reduces monopolisation. Overall, the internationalisation of DPIs is crucial for advancing global digital inclusion, economic cooperation, and technological self-reliance.

Key Takeaways

The first session on DPI Sutras during the ORF-CDPG Tech Huddle[e] reflected on India's DPI journey, spanning principles, design, and the evolution of DPIs as an innovation accelerator. India pioneered the development and diffusion of DPIs, which have increasingly become part of the international agenda for global development. Comprising digital identity, digital payments, and consent architectures, these systems have increased efficiencies across public services and the wider economy. The discussion revolved around India's motivations, the guiding principles of DPI design, and the roadmap for future innovations. The session highlighted a number of relevant takeaways from India's DPI journey:

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[d] 'Internationalisation' refers to the process of adapting and deploying DPI models to different countries and regions.

[e] https://www.iimb.ac.in/cdpg/scripting-inclusive-digital-futures-tech.php

1. **Importance of trust for adoption:** Building trust among citizens and stakeholders is essential for the adoption and scaling of DPI systems at the population level. This involves incorporating principles of transparency, security, and a commitment to the public good.

2. **Modularity and adaptability:** DPI systems must be designed to accommodate diverse needs and contexts. Modular frameworks like MOSIP exemplify how adaptability and customisation can drive global adoption.

3. **DPI Sutras:** Compliance with the principles of citizen-centricity, interoperability, the techno-regulatory approach, non-corporatisation, and non-weaponisation is essential for DPI to deliver its intended benefits to society.

4. **Adaptive learning:** The DPI journey has been characterised by learning from implementation experiences, necessitating proactive monitoring and responsiveness to ensure that systems remain aligned with their founding principles. Conscience keepers play an important role in ensuring this.

5. **Scaling beyond national borders:** The lessons learned during India's DPI journey have informed its design for scalability, helping internationalise DPIs so that other countries can develop efficient, citizen-centric systems for their populations.

Manisha Rathi is a Ph.D. student and a student member at the Center for Digital Public Goods, IIM Bangalore.

Anulekha Nandi is Fellow, Observer Research Foundation. Fellow, Centre for Security, Strategy and Technology, ORF.

The chapter is inspired by the insights shared during the Session on 'DPI Sutras' in 'Tech Huddle | Decoding DPI: Scripting Inclusive Digital Futures' organised jointly by the Observer Research Foundation and Center for Digital Public Goods, IIMB on 7 August 2024. The session reflected on India's DPI journey, spanning the principles, design, and the evolution of DPIs as an accelerator of innovation. The panellists were Sharad Sharma, Co-founder of iSPIRT, and Neha Chaudhari, Partner at Ikigai Law. The session was moderated by Pranjal Sharma, economic analyst and author. The authors have taken key themes identified during the discussions and supplemented them with further research. All views expressed in this essay should be attributed to the authors alone and not the event panellists.

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Private Provisioning of Digital Public Infrastructure

Pramoth Kumar Joseph and Tanusha Tyagi

Infrastructures are the "technologies and systems necessary for society to function."[1] Infrastructure is generally classified as a public good[2] that can be accessed and harnessed by all, independent of the consumption levels of others.[3] This infrastructure can be funded in many ways—notably through sponsorships or provisioning by single or multiple entities. These methods, among other similar avenues, can achieve the scale of investment needed for such infrastructure.

Sponsoring firms invest in an infrastructure (or public good) company, become the project sponsors, and are known as the company's shareholders. When one or more sponsors are involved, a joint-venture agreement is in place. Sponsors have a key role during the early stages of the project: they bring in small equity investments and facilitate external financing by reaching out to other investors (equity and quasi-equity investors), including banks and financial institutions (debt providers). Sponsors typically do not assume any risk arising from project financing, but can intervene

in exceptional circumstances. Some of them are typically contractors, suppliers, or operators involved with the project and could be primary or secondary investors. Sponsors typically stay on till the project is operational or may form partnerships with other long-term sponsors. For the reasons specified, sponsorships fail to scale the investment needs for the larger, all-encompassing scope of infrastructure.

This infrastructure can also be 'provisioned' such that the scale and scope missing in other modes of funding can be accessed. Provisioning as a complex process can cover the entire infrastructure end-to-end, namely: production, distribution, appropriation, and consumption, with specific mechanisms for obtaining these goods and services.[4]

Private Provisioning of Public Goods

Private provisioning of public goods can be achieved in several ways, namely: government-based provisioning, public procurement-driven market-based provisioning, regulated market-based provisioning, and private provisioning.

- Government-based provisioning includes infrastructure provided directly by the government. This typically includes most intangible and institutional infrastructures.
- Public procurement-driven market-based provisioning implies government buying the necessary infrastructure from private companies and providing it to the larger public at a subsidised or zero cost.
- Regulated market-based provisioning allows for government intervention to optimise prices where there is a threat of suboptimal pricing owing to the popularity of the infrastructure and significant economies of scale.
- Private provisioning has surged with the private companies offering infrastructures that were once government or public-owned assets. This has been aided by multi-pronged benefits for the public and freed up government/public ownership and responsibility.

The provision of public infrastructure, including investments, is ridden with doubts about the right quantity and quality levels amidst the changing mindset of governments looking to offload their responsibilities, in part or fully. As private enterprises bring in better service quality, optimised costs, innovations, efficiency gains, and improved competition, governments have stepped back from government-based and public procurement-driven market-based provisioning.[5] This has given rise to public-private partnerships (PPPs) where governments and markets come together in a hybrid approach to maximise benefits for the public.[6]

While public-private partnerships bring benefits, the risk distribution is too high for the participating entities, including the government, owing to the sheer scale of provisioning required. Governance and accountability are key elements in PPPs to align interests, incentives, performance, and risk-sharing.

Private provisioning of public goods can be explained simply as "the provision of collective goods by the private sector."[7] Such private provisioning can take several forms, including through contracts from public agencies, management contracts, vouchers, consumer cooperatives, or monopoly franchises.[8] Daniels and Trebilcock (1996) observe that this could also involve "public ownership with private operation through lease contracts, concessions, or management contracts, while others involve full private ownership and private operation. Yet others involve non-profit operation through local community organisations."[9]

Generally, public sector activities are aimed at meeting community objectives, while the private sector focuses on profit. However, through private provisioning, a private company takes full responsibility for creating and managing a service or infrastructure that benefits the public. Under private provisioning, in its extreme form, a private firm delivers "an asset or service or both in response to market signals" and is responsible for funding the investment. It has full ownership, providing resources to operate the asset, and collects revenue from the user.[10]

Examples of private provisioning of public goods in India include the following:

- Gujarat Port Policies allowing the provision of port-related services such as stevedoring, piloting, tug towing, lighterage, and dredging by private entities.[11]
- Operation of buses in Kolkata by private players to improve connectivity.[12]
- Expansion and operation of Amritsar Bus Terminal by a private firm, improving capacity to handle up to 2,000 buses daily.[13]
- Provision of dialysis services in Andhra Pradesh government hospitals by private healthcare providers, benefiting low-income patients.[14]

This chapter sees how the concept of Digital Public Infrastructure (DPI) aligns with the idea of private provisioning of a public good.

DPI and Private Provisioning

DPIs are foundational digital frameworks designed to achieve societal goals through an ecosystem that encompasses technology, markets, and governance. DPI is defined as "society-wide, digital capabilities essential to participation in society and markets as a citizen, entrepreneur and consumer in a digital era."[16] Built on

interoperable and shared standards, DPIs are designed to enhance digital accessibility and ensure equitable distribution of their benefits. These transformative infrastructures drive economic growth, advance technology, and improve the quality of life for individuals while enabling businesses to operate fairly and effectively. The attributes and functions of the infrastructure are two key parameters that can be used to assess the public benefits generated through DPI as a key enabler for digital transformation. The former could be technical attributes leading to improved efficiency and scalability, whereas the latter could be a functional view of infrastructure, which leads to societal benefits.[17]

Foundational DPIs utilise various platforms to bring together identification (ID), payments, and data exchange systems so that countries can deliver key services to their citizens.[18] DPIs also help improve the delivery of government services, participation of the general public in e-government, and foster more regional cooperation.[19]

The onus for the growth of DPI lies with both the government and the private sector. Both public and private investment are important for the success of DPI, and different funding and institutional arrangements are used to support such initiatives.[20]

Private Participation for Implementation of DPI

Establishing foundational structures, such as DPI in itself, is not sufficient, and it is important to build services on top of this infrastructure to support innovation at scale.[21] While the Government of India has laid the foundation for DPI, private entities have played an integral role in developing innovative solutions on top of the foundational layer.

Unified Payments Interface (UPI) serves as an excellent case study of how private sector participation can enhance the reach and impact of a DPI. UPI is run by the National Payments Corporation of India (NPCI), an umbrella organisation for operating retail payments and settlement systems in India, under the provisions of the Payment and Settlement Systems Act, 2007, for creating a robust Payment and Settlement Infrastructure in India.[a,22]

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[a] The 10 promoters include public-sector banks as well as private-sector banks, such as the State Bank of India, Punjab National Bank, Canara Bank, Bank of Baroda, Union Bank of India, Bank of India, ICICI Bank Limited, HDFC Bank Limited, Citibank N. A., and HSBC.

In addition, the private sector has invested heavily in marketing and creating user-friendly interfaces to improve the adoption of the solution. By using interactive user interface (UI), QR code-based payments, and cashback incentives, private players are able to attract more customers onto their platforms. These efforts have made digital payments more accessible and appealing to the public, driving widespread adoption in both urban and rural regions. By tailoring solutions to meet diverse user needs, private players have amplified the platform's utility and ensured its seamless integration into daily life. Today, companies like PhonePe and Google Pay dominate the UPI ecosystem and process over 93 percent of all transactions across the country.[23]

India has taken steps to incorporate the private sector in its DPI-building efforts, while Aadhaar serves as an example of public infrastructure. UPI, managed by the NPCI, and the Account Aggregator (AA) ecosystem under Data Empowerment and Protection Architecture (DEPA), governed by Sahamati (an industry-led body),[24] highlight the role of the private sector. This approach allows private players to leverage their resources, expertise, and innovation capabilities to propel ecosystem development and achieve market penetration.

Private Sector Contributions

While the government has laid key foundational structures for DPI systems in India, there are concerns around the lack of technical skills and the inadequacy in designing tailored solutions. These are the qualities that the private sector is well equipped to provide.[25] The private sector, as frontline executors, have a deep understanding of the opportunities and challenges faced by both, consumers and markets. Accordingly, the governments can focus more on policy-level solutions and deliverables for citizens.[26] The following are some of what the private sector can offer:

Technical Skills and Specialisations

Governments often lack specialised talent to cater to ever-growing technological advancements. Developing and maintaining DPI requires continuous technological upgrades and advanced expertise, which government agencies may struggle to source or retain due to bureaucratic hiring processes and less-competitive salaries. India's Unique Identification Authority of India (UIDAI) Aadhaar programme was built in partnership with private sector technology experts such as Infosys co-founder Nandan Nilekani.[27]

Ability to Offer Tailored Solutions

Government-driven initiatives often take a one-size-fits-all approach, focusing on broad coverage rather than customised services. DPIs, on the other hand, cater to diverse user bases with varied needs across sectors such as finance, healthcare, agriculture, and education.[28] Private companies are adept at identifying and addressing specific market demands through user-centric design, data-driven insights, and iterative innovation. Their ability to develop tailored solutions ensures that DPI services resonate more effectively with end-users, driving adoption and satisfaction.

Greater Efficiencies

Governments, constrained by administrative processes and bureaucratic decision-making, often operate at a slower pace than private entities. This inherent inefficiency can result in delays in project implementation, slower response times to user needs, and an inability to rapidly adapt to technological advancements or market changes. Conversely, private organisations, driven by competition and profit motives, are incentivised to optimise their operations, reduce costs, and deliver high-quality services efficiently. For instance, the rapid scaling of UPI was made possible by private players developing user-friendly apps and integrating value-added services, showcasing how efficiency drives growth and adoption.

Competition or Wider Participation

Improved efficiencies from effective management by the private sector leads to increased competition in the economy and wider participation in DPI initiatives. The initial euphoria and rush to implement UPI-enabled solutions led to faster adoption. As these private entities focused on reduced costs and optimised profits, the increased competition slowly narrowed to a few key players dominating the market.

Ecosystem Integration

Choudhuri et al., in their research, outline Ecosystem Integration as one of the six key determinants for urban digital infrastructure.[29] The urban digital infrastructure ecosystem involves participation from government, private entities, and the general public and it is viewed as a multi-dimensional entity with integration—both vertical and horizontal—from technology providers, industry players, and citizens. Such integration fosters innovation, leading to the emergence of new business models that can shape and influence social behaviours.

A striking example of this transformation is India's shift from a largely cash-based economy, supported by a range of institutions and public engagement, to a digital, platform-driven ecosystem. This shift has been catalysed by UPI, with fintech firms playing a role in driving innovation and delivering novel financial services.[30]

Public-Private Partnership Model for DPI

PPP models can be effectively leveraged to drive the implementation of DPI by combining the strengths of both sectors.[31] Governments bring regulatory oversight, public trust, and access to underserved populations, while private players contribute technology, innovation, and operational efficiency.[32] Companies add value not only through financial investments but also through technological innovation, expertise, and strategic partnerships.[33] More importantly, by establishing PPPs, companies can unlock capital and make public projects more efficient and innovative.

The best outcomes are achieved when the public and private sectors collaborate to develop robust DPI.[34] By way of collaboration, the private sector's market insights and financial resources are combined with the government's existing policies, which creates a synergy that yields optimal outcomes for all stakeholders. This approach allows the private sector to leverage its innovative capabilities and customer-centric strategies, while the government ensures alignment with public welfare goals and regulatory frameworks.

Way Forward

DPI implementation has achieved great success in India due to its innovative approach of bringing public-private partnerships to the forefront. Collaboration between private players and various other stakeholders with the government has allowed such a solution to reach the scale of adoption seen today. However, to ensure the continued participation of the private sector, it will be crucial to align the incentives of these businesses with the broader goals of DPI. For private enterprises to actively engage in the development and scaling of DPI, it is important to develop a viable profit motive. In the absence of such a motive, the private sector may not have any enthusiasm for innovating, expanding, or building on the DPI ecosystem. It is important to develop a sustainable economic model to attract sustained private sector participation. This will require the creation of frameworks that allow businesses to monetise their offerings while ensuring affordability and accessibility for the public.

Further, it is important to design the appropriate regulatory framework to foster private sector participation in DPI implementation. Clear regulations will provide much-needed predictability, leading to informed investment decisions. This combination of

regulatory clarity and legal safeguards creates a conducive environment for private sector investment and innovation. Additionally, India must also create an enabling environment that fosters collaboration, innovation, and mutual trust.[35] A key step would be to provide streamlined policies and regulatory frameworks to reduce regulatory obstacles and offer clear guidelines that encourage private investment in DPI projects.

Pramoth Kumar Joseph is a Ph.D. student and a student member, Center for Digital Public Goods, IIM Bangalore.

Tanusha Tyagi is Research Assistant, Centre for Digital Societies, ORF.

This chapter is inspired by the discussions during the session, "Privately Provisioned Public Infrastructure" in "Tech Huddle | Decoding DPI: Scripting Inclusive Digital Futures" organised jointly by the Observer Research Foundation and the Center for Digital Public Goods, IIMB on 7 August 2024. The authors have taken key themes identified during the discussions and supplemented them with further research. All views expressed in this essay should be attributed to the authors alone and not the event panellists.

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DPI: Balancing Innovation and Competition

Anuradha Sharma and Basu Chandola

A digital economy relies on foundational infrastructure to support innovation and growth at scale. Typically, the digital infrastructure of any country is either proprietary or driven by government initiatives.[1] For its part, India has developed a Digital Public Infrastructure (DPI) approach that harnesses the potential of technology for public interest by combining private innovation with regulatory guardrails.[2]

DPI comprises modular building blocks—digital identity (ID) systems, digital payments, and consent-based data sharing—that serve multiple purposes across the digital space. These assets are employed by the government, the private sector, and civil society to participate in the digital ecosystem.[3] Alternatively, DPIs can be envisioned as a platform that allows other entities to "plug and play" their solutions on the foundational rails.[4] Standards for these public platforms are developed collaboratively by organisations, improving their scalability and adoption.[5] DPI provides core technological capabilities that can be used by entrepreneurial actors to build innovative solutions.[6]

DPIs facilitate innovation and promote entrepreneurship by allowing enterprises to design novel applications on the DPI layers. Such applications can improve consumer experience and influence competition, collaboration, and market power in the digital markets. The public-private model leveraging Aadhaar, Unified Payments Interface (UPI), and the Account Aggregator (AA) allows for the balance between state-led architecture and proprietary applications.[7] This article examines DPI's transformative impact on innovation, entrepreneurship, and competition while highlighting crucial elements like governance, trust, and associated challenges in the propagation of DPI use across the economy.

DPI as a Foundational Layer for Innovation

DPI has facilitated groundbreaking innovations in India. The government provides the foundational layer, while the private sector builds innovative products and solutions on top of it.[8] This public-private partnership is a distinctive feature that promotes innovation across sectors such as fintech, healthcare, and education.[9] DPI lowers the cost of doing business,[10] allowing for entrepreneurship and experimentation.[11] The 2024 Budget emphasises the role of DPI in boosting productivity, creating business opportunities, and fostering private-sector innovation.[12] India, thus, has multiple successful examples of homegrown innovations facilitated by the India Stack.[a]

The UPI is India's homegrown real-time mobile payment system, built upon Aadhaar and other layers of the open-source India Stack. It enables users to access several bank accounts through a single mobile application, offering several banking features. By enabling instant, 24/7 money transfers, UPI has been able to successfully integrate itself into India's payment ecosystem, revolutionising transaction processes.[13] In December 2024 alone, UPI recorded over 16.73 billion transactions worth INR 23.25 lakh crore.

Similarly, the AA system operates on the 'data' layer of the India Stack.[14] Introduced as a consent-based financial data-sharing system, it enables the retrieval of a customer's financial information[15] without the need for physical documents. Between 2021 and 2024, the AA framework crossed 100 million consents and is expected to achieve a penetration rate of 25-30 percent of the Indian population by 2025.[16]

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[a] 'India Stack' is the moniker for a set of open APIs and digital public goods that aim to unlock the economic primitives of identity, data, and payments at population scale. These include digital identity, payment system, data and open networks. https://indiastack.org/index.html

The scale and impact of DPI-based innovation is massive. Electronic Know Your Customer (eKYC) verification through Aadhaar—using biometric information and mobile phones—has helped advance India's financial sector. There have been over 22 billion eKYC transactions to date,[17] providing a simpler KYC process for all parties that is paperless, secure, consent-based, and cost-efficient.[18]

The aggregate effect of these infrastructural layers has created a networked innovation landscape, which can be leveraged by the private sector for scaling in terms of growth and novelty across India.

Design Benefits

DPI is an infrastructural platform created as a set of shared, interoperable digital foundational blocks. Designed around three core layers—i.e., identity, payments, and data—DPI's modular structure supports innovation while providing a level playing field that promotes competition.[19] These features allow its components to be rearranged to create new opportunities and solutions.[20] DPI's design also facilitates regulatory updates that increase compatibility across solutions and bring in new discoverable opportunities among service providers. Such solutions include UPI-based digital wallets with full KYC,[21] and Aadhaar-based DigiLocker services.[22] These use cases can be both standalone and composite. The inherent interoperability and modularity of DPI encourage immediate private-sector innovation. Another use case for these features is where mobile numbers and bank accounts can be bundled and connected to build a base for UPI solutions in financial services applications. Such recombination encourages the possibility of new entrepreneurial initiatives and also provides the platform for even new digital services like the Central Bank Digital Currency (CBDC)/ e-Rupee, which shall utilise the UPI QR codes for future operations.[23]

DPI thus provides the base rails for layers of innovation that serve the larger part of the population, enabling formalisation and digitalisation. It is creating digital footprints for every citizen while generating vast volumes of data. With characteristics like interoperability, low-cost access, and transparency, DPI systems are inherently inclusive and equitable.[24]

Data-Driven Infrastructure

A core purpose of DPI is to allow institutions and entities to use the vast amounts of data safely and securely. However, challenges remain around quality and availability of data, leakage, misuse, and control over data flow. India had earlier lacked a mechanism to use population-wide available data for monetisation and inclusivity, with access largely limited to banks and other financial institutions.

The creation of the Data Empowerment and Protection Architecture (DEPA) and the AA gives other entities a chance to use the previously siloed data through standards and open APIs.[25] Interoperability strengthens the system, while open standards democratise data use and encourage innovation. As of November 2024, some 410 financial institutions had gone live as Financial Information Users (FIUs), and more than 100 million users had linked their accounts to the AA framework.[26] This not only drives data-based processes but also reduces paperwork and associated barriers. However, the benefits come with the challenge of possible underutilisation and under-commoditisation of data by entrepreneurial ventures. An oversupply of data as capital could emerge if innovation does not keep pace.

Data availability and associated opportunities also emphasise the need for population-scale mechanisms that empower citizens while safeguarding data integrity. The importance of educating people on DPIs at the basic academic level to bridge knowledge gaps regarding data supply and usage is a required approach. The challenge lies in creating standards and interoperability while enabling innovation without compromising on data privacy, security, and public understanding.[27] The internet has always been viewed as a free infrastructure, monetised by private players through advertisements and similar methods. The point of discussion is how entrepreneurs can commercialise DPI. Is DPI supposed to be a means to power pure-play and create sustainable and scalable business models? Or is DPI to be viewed as a point of entry for players to build businesses in the foundational layer itself? Or both? The opportunities are vast and open to all.

Governance, Security, and Trust

Trust and security are crucial for DPI adoption. For instance, the Aadhaar system is centralised and stores minimal information during enrolment and updates. The Unique Identification Authority of India (UIDAI)[b] handles authentication when the Aadhaar ID is used,[28] ensuring scalability and security for this DPI layer. Meanwhile, decentralised models like the Open Network for Digital Commerce (ONDC) might seem to present a risk due to their unbundled nature. However, like the UIDAI precautions, data security is maintained by anonymising most of the data within the open network.[29] Such a trust-based architecture, which separates authentication from credentialing helps mitigate risks in the DPI ecosystem while assuring the associated actors of its viability.

[b] UIDAI is the statutory authority established by the Government of India to issue and manage the Aadhaar. https://uidai.gov.in/en/about-uidai/unique-identification-authority-of-india.html

The risk of data breaches drives continuous advancements in regulatory overview, consent-based protocols, and updated standards for encryption and anonymity. Secure data exchanges and appropriate regulatory oversight are required for enabling innovation in a secure environment. Both the DEPA and the associated AA framework give users control over their data usage, particularly concerning personal financial information. These mark the characteristics of a 'good' digital public infrastructure.[30]

Regulation has been crucial in shaping the trajectory and evolution of India's DPI. India's regulatory approach fosters innovation while reducing risks. Open standards and a collaborative governance model have facilitated the development of standardised interfaces for systems and applications, reducing entry barriers. This approach has guided actors in realising their vision in a community-driven way and encouraged the creation of inclusive business models.[31]

Public-Private Collaboration and Commercially Viable Business Models

India's DPI model differs from that of, for example, the United States (US), where capital markets and proprietary/private-sector solutions drive private growth, and China, which follows a state-controlled approach.[32] India's DPI approach is guided by regulatory frameworks that provide structural flexibility. The collaborations between central regulatory bodies like the Reserve Bank of India (RBI) and private fintech startups have increased economic benefits and supported the adoption of novel solutions. For such models to achieve sustainable growth, there is need for improved administration in access, democratisation, and development. India achieves this through India Stack, which ensures data empowerment and protection through consented data sharing,[33] and increases inclusion and accessibility.

The sustainability of DPI-based solutions depends on the creation of economically viable business models. While UPI has met with success, payment service providers need sustained revenue and bankable business models to continue innovation.[34] Without monetisation possibilities, private-sector engagement may decline, restricting innovation. Though digitalisation levels the playing field and democratises innovation,[35] future DPI-driven models must consider:

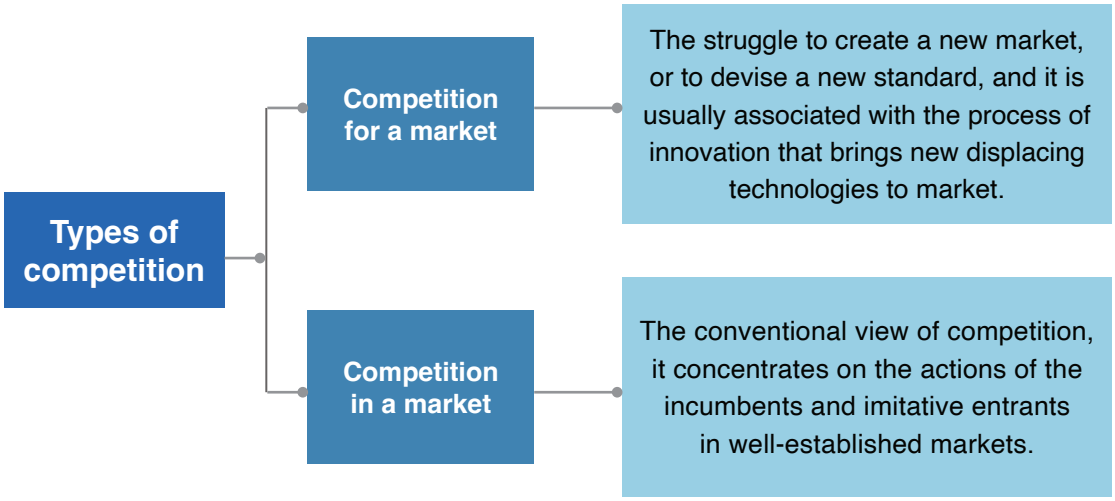
- **Incentivisation:** Allowing regulated and accessible commercial applications of DPI layers for entrepreneurship,
- **Balancing accessibility and viability:** Ensuring that inclusivity does not dominate the commercial revenue generation.
- **Data-driven business models:** Integrating consent-based data access enabling easy commercialisation and revenue generation.

DPI and Competition

DPIs can have two kinds of competitive effects.[36] On one hand, their open-access[c] nature levels the playing field and fosters competition.[37] Since DPI-based solutions are interoperable, there is no customer lock-in, allowing users to shift to different operators and limiting network effects. Interoperability allows interaction and collaboration within the ecosystem, facilitating competition across sectors.[38] On the other hand, there are concerns around the possible competition harms due to the deployment of DPIs and the creation of infrastructural monopolies.[39]

Digital platforms use technologies to facilitate interactions, exhibiting characteristics like strong network effects, economies of scope and scale, and the use of digital data.[40] In addition to "competition in a market", digital economies observe "competition for a market" (see Figure 1).

Figure 1: Types of Competition



Source: Based on PA Geroski, "Competition in Markets and Competition for Markets"[41]

[c] 'Open access' means free access to information and unrestricted use of electronic resources for everyone. https://www.unesco.org/en/open-access

Digital markets are often characterised by competition for a market rather than competition in the market.[42] In such a situation, the race is effectively won when the first entrant establishes dominance,[43] but this position remains contestable as new platforms may emerge due to innovation. Competitive constraints in these markets arise from the introduction of new products.[44] DPI-based innovative solutions can have competitive concerns like any other digital platform. UPI is a good example to assess the impact of DPI-led solutions on the market.

From a competition perspective, UPI possesses two kinds of concentration risks. The National Payments Corporation of India (NPCI) is the only organisation authorised by the RBI to operate UPI's retail payment solutions,[45] effectively giving UPI a legal monopoly. Further, there are risks about concentration on the UPI platform itself, with PhonePe and Google Pay controlling over 85 percent of the total market share.[46] Smaller and newer players face entry barriers due to entrenched market positions and the need for huge marketing budgets.[47] While the NPCI has tried to impose a 30-percent market share cap on UPI apps,[48] implementation has been delayed,[49] and the impact of such caps on innovation and competition remains uncertain.[50]

While the open-access and interoperability aspects of DPI should promote competition, UPI clearly tells another story. There is limited "competition in the market" for UPI, as evidenced by the duopoly in the market share, and there is no possibility of "competition for the market" as UPI is a legal monopoly, with no possibility for the creation of a new innovative products or solutions. Such risk of DPIs causing market concentration needs to be mitigated.[51]

Way Forward

This chapter sought to demonstrate that while DPI can have pro-competitive effects, there are risks around market share concentration. DPI-based solutions need to be designed after assessing their competitive effects,[52] supported by data-driven evidence. Measures must be designed to ensure that DPI promotes healthy competition and innovation. A competition-focused design for DPI is necessary for fostering innovation and improving customer experience. While addressing issues like potential monopolies and exclusion risks, DPI requires regular assessment to ensure progress and wider adoption.[53]

DPI-based discussions have been at the forefront in the G20 presidency[d] and have captured widespread attention across the globe.[54] DPI is viewed as a way to

[d] The G20 presidency is a rotating annual role within a group of 20 economies. It steers the G20 agenda for one year and hosts the Summit. https://www.g20.in/en/about-g20/about-g20.html

counterbalance private infrastructure by incorporating social benefits. This highlights the requirement for education and awareness about public infrastructures and best practices for their use. Practical problems, such as the digital divide, low digital literacy, and resistance to change, are prevalent among incumbents. These can be overcome by awareness, transparency, and trust-building with users. The legal aspects of DPI governance and data handling also require further clarification from central regulatory bodies.

While DPI does not necessarily require extensive digital artefacts like smartphones, it drives private innovation, fosters healthy competition, and creates nationwide scale with its minimalist approach.[55] Its full potential regarding public-private collaboration, regulatory coverage, and accessibility for even the smallest entities remains to be seen. DPI is increasingly viewed as "DaaS (DPI as a Service)" for rapid, scalable deployment via cloud-ready means.[56]

The next step is to integrate Artificial Intelligence (AI) into a robust and responsible DPI to escalate the capabilities, along with cross-border functionalities through tokenised systems like the CBDC and/or exporting digital layers to other countries, making it a multi-country phenomenon.[57] Starting from laying the groundwork for the JAM Trinity—the initiative of the Indian government for linking the Jan Dhan Accounts (J), Aadhaar (A), and Mobile phones (M) to facilitate Direct Benefit Transfers and promote financial inclusion—to the adoption of UPI by other countries, this India-bred phenomenon has come a long way.

Anuradha Sharma is a PhD student, IIM Bangalore.

Basu Chandola is Associate Fellow, Centre for Digital Societies, ORF.

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Conclusion

Anirban Sarma, Srinivasan R, and Pranjal Sharma

The DPI Imperative

This volume has illustrated the character of digital public infrastructure (DPI) as a population-scale technology system that enables the flow of individuals (through unique digital identity systems), money (through real-time, fast payment systems), and information (through consent-based, privacy-protecting, data-sharing frameworks).[1] India's pioneering architecture, India Stack, made it the first country to develop all three foundational DPIs: Aadhaar (unique identity), the Unified Payments Interface (UPI), and the Data Empowerment and Protection Architecture (DEPA).

Together, these three layers have revolutionised public service delivery and facilitated digital transformation at an unprecedented scale. As of May 2025, over 99.9 percent of Indian adults have an Aadhaar number, which they use at least once a month to access public and private services.[2] Indians make an average of 500 million UPI transactions daily.[3] DEPA

is changing the national credit landscape,[4] driving innovation and galvanising the startup ecosystem by allowing new applications to be built on top of its layers.[5]

At the same time, the new privacy rules being finalised under the Digital Personal Data Protection (DPDP) Act, 2023, must be considered in any discussion about DPI. As India's DPI ecosystem matures, regulatory and legal frameworks will influence the manner in which it functions.[6] While early-stage DPI platforms benefitted from a first-mover advantage, the next phase will require stronger safeguards. Such regulations could stifle innovation, making it essential to find a nuanced balance between oversight and growth.

Given DPIs' low cost and scalability, other countries have shown an active interest in establishing similar infrastructures. India has taken a leading role in advancing dialogue and cooperation to support their creation.

Since 2018, India's Modular Open-Source Identity Platform (MOSIP) has helped over 20 countries develop their digital ID systems, and the UPI is now available and used in seven others. In December 2024, India entered into a DPI partnership with Sri Lanka,[7] and is also presently exploring the possibility of helping a number of African and South American countries build their own UPI-like payment systems.[8]

It was in 2023, during India's G20 presidency, that global interest in DPI increased remarkably. That year, India signed DPI-related MOUs with eight developing countries;[9] the European Union (EU) and India agreed to collaborate on improving the interoperability of their respective DPIs;[10] and following Prime Minister Narendra Modi's historic US visit, the two countries announced that they would work together to "provide global leadership for the implementation of DPI."[11] One of the outcomes was the creation of the Global DPI Registry (GDPIR) in November 2023, a resource compiling DPI lessons and knowledge available from G20 and guest countries.[12] The subsequent presidencies of Brazil and South Africa have seen the G20 retain a core focus on promoting DPI.

First Principles

As DPIs continue to gain traction around the world and their rollouts accelerate, certain fundamental principles must be kept in mind.

- **Building public trust:** DPIs must incorporate principles of transparency, security, and a commitment to the public good to earn citizens' trust. This foundation of trust and accountability is key to driving widespread adoption.

- **Adopting open, modular, and customisable approaches:** DPI systems should be designed in an inclusive manner to accommodate the needs of diverse communities and contexts.[13] Moreover, the constituents of DPI should be open, interoperable, modular, and customisable, enabling combinatorial innovation during deployment.

- **Operationalising the DPI Sutras:** The DPI Sutras combine citizen-centric and open, modular architecture with the wider principles of crafting techno-legal regulation (which ensures technological soundness and legal compliance); preventing the corporatisation or monopolisation of DPIs (to maintain a level playing field); and embedding measures to prevent the weaponisation of DPIs.

- **Undertaking adaptive and continuous learning:** As DPIs are deployed in different geographies, the lessons learned from their implementation must feed back into future DPI-building efforts. Proactive monitoring and responses are needed, and this function is best entrusted to "conscience keepers", such as public-spirited and public-driven entities.

Private Provisioning and Economic Sustainability

Foundational structures like DPI are insufficient without consumer-facing applications built upon them. The private sector—with its deep understanding of markets and consumer behaviour—is often best placed to innovate and provide these services. While this has been its most recognised function with respect to DPI, the private sector also contributes to DPI provisioning in other ways.

- **Building DPI and boosting its reach and impact:** The National Payments Corporation of India (NPCI), promoted by 10 banks including private institutions, integrates private sector participation into the governance, design, and management of the UPI. In 2016, NPCI's shareholding broadened to include 56 member banks from both the private and public sectors.[14] The NPCI has continued to innovate, releasing successive and improved versions of UPI. UPI 2.0, launched in 2018, included a series of new features and is widely regarded as being more user-friendly than UPI 1.0.[15] Similarly, Sahamati—an industry-led body—governs the evolving Account Aggregator ecosystem under DEPA. These examples demonstrate the private sector's successful contributions to the construction and governance of DPI and enhancing its reach and impact.

- **Maintaining and upgrading DPI:** The private sector can provide the technical maintenance and upgrades required for DPIs to function optimally. This could include sourcing and deputing trained technical personnel—a process often more complex and cumbersome for government agencies.

- **Promoting innovation, efficiencies, and competition:** DPIs' open Application Programming Interfaces (APIs) allow businesses of all sizes to integrate with the DPI layers and build atop them without the need for heavy infrastructure investment. This levels the playing field, allowing firms to focus on developing innovative, value-added solutions.[16] Driven by competition and the profit motive, businesses strive to increase efficiencies, optimise costs, and improve service quality. This creates a virtuous cycle: competition lowers costs and boosts quality, which in turn intensifies competition.

- **Fostering public-private partnerships (PPPs):** PPPs offer a viable approach for advancing DPIs. Governments provide regulatory oversight, stability, and a mandate to serve traditionally neglected populations, while the private sector brings financial resources, technology, innovation, and operational efficiency. Such collaborations can be mutually beneficial, but businesses need clear incentives to help develop and scale DPI. Without a clear profit motive and sustained monetisation opportunities, the private sector may take little interest in strengthening the DPI ecosystem.

  At a fundamental level, investing in the physical infrastructure for affordable connectivity is crucial. BSNL's role, along with its collaborations with private players to expand the BharatNet broadband network across India, will be an important determinant of DPIs' growth and success.[17]

- **Implementing DPIs at population scale:** Effective DPI implementation at scale requires ecosystem participants to leverage their strengths and capabilities. Governments excel at convening stakeholders; the private sector drives investment and rapid deployment; and civil society provides oversight and fosters equity, fairness, and inclusion.

Upscaling the Innovation Ecosystem

The most pronounced outcome of the DPI revolution has been its impact on innovation. Amitabh Kant, India's G20 Sherpa, has emphasised this, declaring: "The future will not be driven by Big Tech, it will be driven by DPI."[18]

According to Kant, "In the last two and a half decades, all innovation and tech breakthroughs stemmed from the American Big Tech model." But the pioneering Indian approach of allowing the private sector to build and run their solutions on a foundation of DPI has unleashed a "huge amount of innovation."[19] Indeed, the success of India's thriving startup sector, especially in fintech, owes much to the robustness of the country's DPI.

- **Building a networked innovation landscape:** India Stack has enabled homegrown innovation. The organic integration of UPI with India's payment ecosystems has catalysed the speed and scale of digital transactions.[a] Similarly, over 100 million individuals have consented to share financial data under the Account Aggregator system, prompting the creation of a new wave of personalised financial products and services. Aadhaar-based, paperless eKYC verifications have also driven exponential growth in the financial sector. These developments have created a highly networked innovation landscape that businesses can easily leverage.

  DPI-led learning and innovation are expanding beyond fintech. For example, the Insurance Regulatory and Development Authority of India (IRDAI) is launching Bima Sugam, a platform that unites web aggregators, brokers, insurers, and bank agents to sell insurance policies.[20] Accessible to policyholders with an e-insurance account, Bima Sugam aims to use a public national network to improve insurance accessibility and support IRDAI's goal of ensuring 'insurance for all' by 2047.[21]

- **Making data available securely:** Before DPI, India lacked mechanisms to access a rich, inclusive corpus of population-wide data that could be accessed and monetised with users' explicit consent. DEPA and Account Aggregators now allow certain kinds of previously siloed data to be used by institutions and entities in a safe, secure, and transparent manner, and this has encouraged data-driven innovation. However, the legal aspects of data governance in the context of DPI still require further deliberation and clarity.

- **Foreclosing competition:** While the open-access, interoperable nature of DPIs often levels the playing field, it can also limit competition. For instance, UPI is the only retail payment platform that the Reserve Bank of India allows the NPCI to operate, effectively granting it a legal monopoly. Moreover, market concentration on the UPI platform is high—PhonePe and Google Pay together hold 85 percent of the market, forming a duopoly. For smaller players, entry barriers remain high. Such anticompetitive risks must be mitigated.

- **Navigating new directions:** As India's AI ambitions grow,[22] the intersection of AI and DPI must be explored more closely. AI could enhance DPIs by improving inclusiveness—through AI-powered language translation and user assistance—and safety, via fraud detection tools. Conversely, DPI can facilitate AI development. Under DEPA 2.0, for instance, India is piloting Confidential Clean Rooms, which are "secure computing environments where sensitive data can be accessed in an algorithmically controlled manner for model training."[23] The convergence of AI and DPI could usher in a new era of innovation.

Anirban Sarma is Director, Centre for Digital Societies, ORF.

Srinivasan R is Professor of Strategy and Chairperson, Center for Digital Public Goods, IIM Bangalore.

Pranjal Sharma is Non-Resident Fellow, ORF Middle East, and an economic analyst and author.

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Indian Institute of Management Bangalore
Bannerghatta Road,
Bangalore 560076.
www.iimb.ac.in/cdpg/index.php I cdpg@iimb.ac.in

20 Rouse Avenue,
New Delhi-110002.
Ph: +91-11-35332000. Fax: +91-11-35332005
www.orfonline.org I contactus@orfonline.org