DPI: Rewriting the Rules of Commerce

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October 2025

ARTHA GLOBAL

Acknowledgement
This paper was undertaken with support from Co-Develop as a part of a series of research papers investigating how DPI generates value and fosters innovation in the commercial sphere.

This paper is not yet available for citation.

About Artha Global
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Artha Global was founded by the leadership team of IDFC Institute, a Mumbai-based think/do tank with over a decade's experience working with the Union, state and local government in India.

1. Introduction

Across many countries, governments are investing in new forms of digital public infrastructure (DPI), including foundational identity systems, instant payment platforms, and consent-based data-sharing mechanisms, to dismantle long-standing obstacles to economic activity. These open, interoperable systems are being deployed across diverse institutional contexts (Masally et al., 2023). Yet their pace, objectives, and real-world effects vary considerably. Some countries view DPI primarily as a tool to modernise governance, while others increasingly use it to integrate previously excluded or informal economic actors into formal markets (OECD, 2024).

Despite this growing momentum, most analyses remain confined to principles or administrative efficiency. Far less is known about how DPI interacts with economic structures on the ground. There is limited empirical evidence on its direct effects on the firms, entrepreneurs, and workers who drive everyday economic activity.

This paper adopts an inductive approach, drawing on patterns across eight countries: India, Brazil, Estonia, Thailand, South Korea, Nigeria, Zambia, and Singapore - spanning low-, middle-, and high-income contexts, to understand how DPI implementation responds to country-specific challenges, ranging from bridging infrastructural gaps in data-poor environments to expanding capabilities within sophisticated administrative systems The cross-country contrasts show that DPI's economic impact is not automatic: outcomes depend on how infrastructures are designed and integrated to fit local policy imperatives. Transformative outcomes occur when core infrastructure layers combine into a coherent "stack," creating multiplier effects that exceed the sum of individual parts (Clark et al., 2025). Importantly, success is not just an engineering feat but a matter of ecosystem orchestration requiring the state to function both as a strategic builder of foundational rails and a trusted steward of the digital economy's governance (Masally et al., 2023).

This analysis examines four layers of DPI across identity, payments, data sharing, and discovery, that together address key economic frictions in recognition, transaction, trust, and market matching - shaping how economies function. Drawing on the broader literature on transaction costs (Coase, 1937), these frictions can be understood as the costs that determine how easily participants can find one another, establish reliability, and exchange value. The paper considers how DPI reduces these barriers and expands opportunities for participation and productivity across the economy.

By focusing on producers and market actors, this analysis shifts the DPI conversation beyond abstract principles toward a grounded understanding of DPI's real-world economic role. It shows that effective DPI represents not just a technical upgrade, but a fundamental redesign of institutional infrastructure linking state, market, and individual.

The spillovers of DPI are already visible in economic activity:

1. **India/Aadhaar - Instant customer onboarding:** The Economic Survey (2023–24) reports that e-KYC costs dropped from about ₹1,000 ($12) to less than ₹6 ($0.06), significantly reducing onboarding costs and facilitating scale in finance and other sectors (Ministry of Finance, 2024).

2. **Brazil/Pix - SME liquidity & cash flow:** Reuters reporting confirms that Pix charges merchants an average fee of 0.33% of the transaction amount, compared to over 1.13% for debit cards and up to 2.34% for credit cards, improving margins; Pix transactions have surpassed card volumes (IMF, 2023).

3. **Estonia/e-Residency - Global business platform:** Since its launch in 2014, the e-Residency programme has attracted more than 128,000 people from 185 countries, who have founded over 36,000 companies in Estonia. This indicates substantial economic activity. Altogether, it has generated €342M ($397 billion) in direct economic impact for the country (Invest Estonia,

2025).

4. **India/Account Aggregator - Data-driven lending:** Sahamati reports that in FY25, the Account Aggregator ecosystem facilitated approximately ₹1.67 trillion of lending over 18.9 million loans, highlighting significant adoption across loan types and institution categories (Sahamati, 2025).

5. **Singapore/TradeTrust - Trade & SME competitiveness:** TradeTrust - an open-source framework developed by Singapore's Infocomm Media Development Authority (IMDA) to standardise and secure digital trade documents. - reduces documentation costs, fraud risks, and accelerates cross-border trade digitalisation, supporting SME competitiveness, though quantitative SME working-capital impacts are not publicly quantified (IMDA, 2025).

The paper proceeds as follows. Section II outlines the economic logic of DPI, linking its four layers - identity, payments, data sharing, and discovery, to the core market frictions they seek to reduce. Sections III–VI then examine each layer in turn, drawing on comparative country experiences to illustrate how these infrastructures lower barriers to recognition, transaction, trust, and market matching in practice. Section VII shifts from mechanisms to governance, identifying the institutional and ecosystem conditions that enable these infrastructures to function as public goods rather than isolated systems. Section VIII builds on this by tracing pathways to impact, showing how DPI outcomes depend on the alignment of digital, institutional, and economic prerequisites. Together, these sections move from theory to evidence to application, demonstrating that the economic power of DPI lies not in technology itself but in how states orchestrate open, trusted, and interoperable systems that align public purpose with private innovation.

2. The Economic Logic of DPI: Overcoming Market Frictions

At its core, DPI reshapes how economic transactions occur by standardising how information moves between actors. Unlike siloed digital systems or analogue processes, DPI establishes open protocols that allow different systems and applications to communicate seamlessly, regardless of who built them (UNDP, 2023). This technical principle carries a profound economic effect: by creating common rails for identity, data, and value exchange, DPI lowers coordination barriers, curbs the formation of closed digital monopolies, and enables participation across a far wider set of market actors.

Crucially, these protocols are not merely technical standards; they function as new institutional rails for the economy. Their ability to reduce friction depends fundamentally on their governance. In successful implementations, this governance model is often characterised by a public-private partnership where the state's role is not to build everything, but to establish open standards, ensure fair access, and act as a trusted arbiter (The Digital Cooperation Organization, 2025). This has the promise to create a predictable and neutral environment, encouraging private firms to innovate and build services on top of the shared infrastructure.

The economic power of DPI lies in how it systematically reduces the frictions that constrain participation and productivity across recognition, transaction, trust, and market matching. Each reflects a set of persistent costs faced by producers and entrepreneurs, especially smaller or informal ones, in becoming visible, transacting efficiently, establishing credibility, and accessing wider markets. The following subsections illustrate, through country examples, how DPI infrastructure addresses these barriers in practice.

2.1. Recognition: Making Actors Visible and Verifiable

A fundamental barrier to economic participation is that many potential market actors remain *invisible* to formal systems. Informal workers often lack recognised credentials; micro- and small enterprises operate without formal registration; and prospective borrowers cannot be verified by lenders. Without visibility and verifiability, these actors remain excluded from transactions that require proof of identity, eligibility, or reliability.

Digital identity systems and registries directly address this recognition gap. By providing unique, verifiable identifiers and linking them to relevant attributes, they make individuals and firms *legible* to both markets and the state (World Bank, 2021). Foundational IDs enable remote authentication and e-KYC, while sector-specific registries such as those for businesses, taxpayers, or professionals, create the institutional records that underpin participation in digital economies.

Examples across contexts illustrate this enabling role. India's Aadhaar has reduced onboarding costs for financial institutions by making remote e-KYC possible at a fraction of earlier costs.. Zambia's National Registration Card (NRC), now being integrated with mobile SIM registration and social protection databases, is extending verifiable identity coverage to low-income and rural populations. Estonia's e-ID and e-Residency (e-Estonia) allow both individuals and companies to authenticate and sign contracts across public and private services, anchoring a trusted digital environment that enables fully online business formation.

However, recognition alone does not guarantee inclusion. Its effectiveness depends on coverage, accuracy, and trust in how identity data are used. Where enrolment systems are uneven or governance safeguards weak, digital identification can reinforce exclusion rather than alleviate it (United Nations, 2021).

2.2 Transaction: Lowering the Costs of Exchange

Even when participants are visible and verifiable, the act of *transacting* can remain costly and cumbersome especially for small or informal firms and service providers.

Traditional payment systems, paperwork-heavy compliance processes, and fragmented financial networks create delays, high fees, and dependency on intermediaries. These frictions increase the cost of participating in formal markets and reduce liquidity for enterprises that operate on thin margins.

Digital payment and compliance infrastructure within DPI directly addresses these barriers by making value transfer faster, cheaper, and more reliable. Open, real-time payment rails and digital invoicing or tax platforms replace manual reconciliation and reduce the need for physical presence or intermediation.

In India, the Unified Payments Interface (UPI) integrates bank accounts, mobile applications, and QR code systems, making digital payments interoperable and reducing the friction of transferring funds across banks or platforms. Brazil's Pix has enabled similar outcomes. Similarly, Nigeria's NIBSS Instant Payments (NIP) network provides real-time interbank transfers that have shortened settlement times and lowered liquidity-related costs for businesses (Ironsi, 2022).

These innovations also strengthen compliance and record-keeping. India's Goods and Services Tax Network (GSTN), for example, automates invoice matching and tax filing for millions of small firms, making compliance less burdensome and creating a unified transaction history that can later be leveraged for credit.

Together, such systems transform the act of transacting from a manual, high-overhead process into an almost invisible function, reducing negotiation, settlement, and compliance costs and freeing up capital for productive use.

2.3 Trust: Reducing Information Gaps and Strengthening Accountability

For markets to function efficiently, participants must trust that the information and systems on which transactions rely are reliable.

In low-trust or low-documentation environments, uncertainty about counterparties' reliability or the security of data exchange often limits participation. These information asymmetries create barriers to credit, insurance, and cross-border trade, where the absence of verifiable records inflates risk premiums and deters investment.

Countries can mitigate these challenges by establishing data-sharing and consent architectures that allow verified information to circulate securely between institutions. When individuals and firms can use their own data, authenticated through digital IDs and protected by clear consent protocols, to demonstrate reliability, new forms of economic trust become possible.

India's Account Aggregator (AA) framework exemplifies this transformation. By enabling customers to share verified financial data across institutions through consent-based APIs, it has reduced customer acquisition costs for lenders and allowed thin-file borrowers to access credit (Sahamati, 2025).

Singapore's SGFinDex operates on similar principles, allowing citizens to consolidate and share financial data securely across public and private providers. Estonia's X-Road infrastructure extends this logic across sectors, ensuring every data exchange is logged and auditable, reinforcing institutional trust.

These systems represent a shift from *relationship-based* to *infrastructure-based* trust where reliability is guaranteed digital protocols that are transparent, auditable, and legally enforceable. And so the quality of this trust depends on governance, particularly data protection, accountability mechanisms, and clear recourse in case of misuse (World Bank, 2021).

2.4 Market Matching: Enabling Coordination and Competitive Access

Market matching is about how buyers, sellers, service providers, and intermediaries *find each other and compete fairly*.

Even in digital economies, information bottlenecks and platform concentration often distort access to markets. Small producers or service providers may exist online but remain effectively invisible within closed, intermediary-controlled ecosystems.

The discovery and fulfillment layers of DPI tackle this by creating open market protocols that allow different platforms to interoperate and share listings, logistics, and fulfillment data. By lowering coordination and matching costs, they can expand the universe of potential transactions and curb the monopolistic control of digital gatekeepers.

India's Open Network for Digital Commerce (ONDC) is a leading example. Built on open standards, it enables interoperability between e-commerce platforms, allowing any verified seller or buyer to transact across applications. For small retailers, this means access to digital markets without having to join a dominant intermediary's ecosystem. Similarly, Singapore's TradeTrust, an open-source framework for digital trade documentation, enables verifiable cross-border exchange of electronic bills of lading and trade certificates, reducing paperwork, fraud risk, and transaction delays.

In Estonia, the same interoperability logic underpins e-procurement and cross-sector data exchange, allowing firms to participate seamlessly in both domestic and EU-wide tenders.

Such systems not only reduce matching and coordination costs but also expand market contestability. When discovery and fulfillment are governed by open standards rather than private rules, value creation becomes more distributed, allowing smaller players to compete and innovate on top of shared infrastructure.

The value of DPI lies in these combinatorial effects when identity, payments, data sharing, and discovery infrastructures reinforce one another, they generate outcomes that exceed the impact of any individual layer (Eaves & Sandman, 2023).

- **Identity infrastructure** provides the foundation of recognition and trust, establishing verifiable credentials for individuals and firms. It converts previously anonymous actors into participants visible to both markets and the state.

- **Payment infrastructure** operationalises this recognition, creating the rails for value exchange and producing a continuous stream of reliable transaction data.

- **Data-sharing and consent systems** transform those records into economic assets, allowing participants to use verified histories to access credit, insurance, and other services.

- **Discovery and fulfillment layers** connect these capabilities to markets, enabling open and competitive exchange across platforms and borders, and reducing reliance on closed, intermediary-controlled systems (UNCTAD, 2021).

Evidence across countries shows that such first-order reductions in friction can catalyse broader change, helping firms enter formal markets, access finance, and scale more efficiently. However, whether these intermediate shifts translate into sustained growth depends on governance, institutional design, and complementary investments. Ultimately, the durability of DPI's economic impact rests as much on stewardship and accountability as on technical design, including robust legal frameworks for data protection and civil-liberty safeguards (World Bank, 2021).

The following sections examine each layer in turn, drawing on country examples to illustrate how these mechanisms are being implemented and what they mean for firms, entrepreneurs, and workers on the ground.

3. From Invisible to Investable: The Economic Power of Digital Identity

As discussed in the previous section, digital identity infrastructure addresses the "recognition problem" in markets. By providing verifiable credentials, it allows previously informal actors to establish economic legibility, participate in contracts, and access services and finance. For workers and micro-enterprises, this visibility can unlock reputational and transactional histories that form the basis of credit and trust. For governments, it enables more precise delivery of benefits and a broader tax base.

India's Aadhaar illustrates both the promise and the scale of such interventions: by linking with the Pradhan Mantri Jan Dhan Yojana (PMJDY) scheme, it enabled the opening of over 523 million bank accounts, bringing marginalized sections into the formal financial system (Ministry of Electronics and IT, 2024). This Aadhaar-driven approach has not only empowered people but also led to significant savings for the public exchequer by cleansing scheme databases, removing millions of fake, non-existent, and ineligible beneficiaries across multiple government ministries and departments.

While such immediate cost-saving benefits are evident, attributing broader economic effects to digital ID systems is far less straightforward. Digital IDs affect the economy less by producing immediate efficiency gains than by reducing upstream frictions. They ease entry barriers by simplifying eligibility checks and lowering verification costs (making each KYC check faster and cheaper), and enable actors to accumulate a recognised digital history. For micro-entrepreneurs or gig workers, a persistent identifier that links to payment or tax records can gradually build a verifiable reputation, lowering counterparty risk and opening access to credit. These are second-order effects that emerge only when IDs are embedded across multiple public and private systems.[1]

Country experiences show how design and integration choices shape these outcomes. Nigeria's fragmented landscape with separate identifiers for banking (BVN), taxation, and national ID (NIN),

[1] The forthcoming use of Aadhaar-based facial and fingerprint recognition for UPI authentication underscores how embedding digital identity across transactional systems can extend verification beyond access to reputation, reliability, and credit visibility. Payment revolution! Facial recognition, fingerprints to soon authenticate UPI payments, Aadhaar biometric data to be used: Report - The Times of India

created duplication and costs for firms and citizens, while constraining the ability to unify welfare and credit markets. At least 13 federal bodies and several states ran siloed biometric schemes, burning money and resources on parallel systems (World Bank, 2020). In contrast, identity infrastructure that becomes embedded across public and private services like India's Aadhaar enabling eKYC across banking, telecom, and fintech, or Estonia's cross-border e-Residency program that can support virtual company creation in under 18 minutes, can fundamentally alter the economics of market participation (Brown, 2022).

Yet, this transformation is not without significant risks. Centralised digital identity systems can create new avenues for surveillance and control. At the same time, technical or procedural barriers can systematically exclude marginalised groups, turning a tool for inclusion into a mechanism of disenfranchisement (Alston, 2019). The design of these systems, particularly choices around data privacy, legal safeguards, and redress mechanisms, is therefore as critical as the technology itself. Furthermore, the concentration of sensitive personal data creates significant national security risks from cyberattacks. These trade-offs between innovation, security, and sovereignty are central to the strategic design of any national identity system. Importantly, there is no single sequencing model. Some countries have built identity as a foundational layer (India, Estonia), while others began with payments or sectoral identifiers (Nigeria's BVN). What matters for economic impact is less the starting point than whether identity systems eventually evolve into interoperable, multi-use infrastructure. Where that happens, digital identity can shift from a narrow administrative tool to a platform that lowers entry barriers, expands participation, and contributes to more dynamic market growth.

3.1 Forging Foundational Identity in Data-Scarce Environments

For countries with limited legacy infrastructure, the initial challenge of DPI is existential: making citizens and businesses visible to the state and the formal economy for the first time. The following cases illustrate two distinct strategic pathways for building this foundational layer - one a top-down, universal system and the other a bottom-up, problem-specific intervention.

A. Zambia: From Analogue Legacy to Foundational Digital ID

Zambia's identity infrastructure is in the early stages of transformation. Its approach represents a strategic, top-down effort to build a universal, foundational identity system intended to serve as the bedrock for all future digital services. Until recently, the country relied on a paper-based National Registration Card (NRC) system, which provided wide coverage but faced duplication risks, and limited verifiability. The absence of a digital registry or interoperable credentials constrained the efficiency of functions such as subsidy distribution and voter verification, and limited the ability to link identity reliably across public services (Centre for Digital Public Infrastructure & Smart Zambia Institute, 2024)

The Integrated National Registration and Identification System (INRIS), launched in 2022 by Zambia's Ministry of Home Affairs and Internal Security, marks a decisive break from this legacy. Built using the Modular Open Source Identity Platform (MOSIP) - an open-source technology platform for building foundational ID systems, it aims to close this gap through biometric, digital first IDs and mobile enrollment, particularly in rural areas.

INRIS issues biometric identity cards tied to a unique 13-digit number, to all citizens above the age of 16. By mid-2024, around 1.5 million citizens had been enrolled with biometric credentials, while roughly 81% of legacy registration records had been digitised (Chang and Malik, 2024) .

Importantly, INRIS is not a donor-run pilot, but a nationally owned platform housed within the Department of National Registration and overseen by the Presidential Delivery Unit (PDU) - signaling high political commitment and institutional coordination.

In 2024, Zambia began piloting MOSIP's e-Signet for biometric authentication, a move toward making digital ID usable for real-time verification in service delivery. Early uses for INRIS are designed to support a range of use cases including e-KYC for banks and telcos, targeted distribution of subsidies, voter registration, and digital access to public services. The economic impact of INRIS will therefore depend less on enrollment figures alone and more on how effectively it is embedded across government programs, financial services, and private-sector applications.

B. Ethiopia: Biometric Innovation Enabling Commerce in Refugee Economies

Ethiopia's Fayda system demonstrates how biometric identity can unlock access to services and economic participation in the most challenging contexts. In contrast to Zambia's registry-first system-building, Ethiopia's Fayda reflects a service-integration approach, extending national digital ID to refugees and other underserved groups from the outset and positioning it as a gateway to banking, SIM access, and public services, laying the foundation for more inclusive and formal economic participation over time. In refugee camps where traditional banking was impossible and aid distribution created parallel economies, Fayda's biometric ID system has enabled refugees to engage in formal commerce for the first time and enter labour markets, and increased ease of doing business by making it easier to obtain business permits. (Dadi, 2024). Mobile traders now accept biometric authentication for purchases, creating transaction histories that qualify refugees for microloans from NGO-backed lenders. Recent funding of $350 million from the Identification for Development (ID4D) initiative enables Fayda's rollout to 90 million Ethiopian nationals and legal residents, including nearly one million refugees (World Bank Group, 2024). Following a three month pilot in 2024, over 9,000 IDs with a unique Fayda number have been distributed in the Addis Ababa region, with over 25,000 refugees consenting their participation (UNHCR, 2024). With over 4 million internally displaced people in Ethiopia and over a million refugees and asylum seekers (UNHCR, 2024), Fayda aims to not only improve quality of life but also foster social cohesion and economic contribution. The potential for economic inclusion extends beyond camps. The recent launch of the Fayda Wallet aims to extend financial inclusion, with the ID supporting real-time authentication and efficient eKYC processes across sectors. As of June 2025, The Cooperative Bank of Oromia is the first financial institution to integrate with the Fayda Wallet, enabling new account openings via biometric eKYC verification without requiring physical documents. This aligns with Ethiopia's policy mandating the use of Fayda IDs for all banking transactions by 2026, a move to strengthen formal identification processes across the financial and banking sectors (ID Tech, 2025).

3.2 Overcoming Fragmentation to Unlock Economic Scale

In more developed but institutionally complex environments, the primary obstacle is often not a lack of identity systems, but a surplus of them. The economic prize lies in overcoming the friction of fragmented, siloed databases to create a unified, interoperable identity layer that can function at national scale.

A. Brazil: Unifying Systems to Spur Formal Entrepreneurship

In Brazil, where the formal identity number (Cadastro de Pessoas Físicas – CPF) underpins most economic transactions, institutional fragmentation has long constrained enterprise formation and efficiency. The turning point came with the consolidation of services under gov.br, which rationalised a maze of federal, state, and municipal portals into a single digital gateway By May 2022, roughly 78% of ~4,900 federal services had been fully digitised, with government estimates of ~BRL 4.5 billion per year in savings. In 2025, inter-agency data-sharing via Conecta GOV.BR added > BRL 5 billion in estimated savings year-to-date - evidence that integration is translating into measurable efficiency, not just enrollment. Adoption is broad: 165 million+ accounts exist on gov.br, and 130.6 million people used at least one digital service in 2025 (Pizzolato Gonçalves & Venijio Maggion, 2022).

Crucially, federated authentication now extends digital identity beyond the state. Through bank-credential logins ("Login Único"), users can elevate account assurance levels and access services; multiple major banks are accredited, allowing firms to verify customers and onboard them digitally with higher confidence and lower cost.

Taken together, gov.br's consolidation, data-sharing, and federated authentication have shifted the business experience from paperwork and queueing to faster formation, lower compliance overhead, and quicker access to markets and finance - the kind of friction reductions that raise private-sector productivity and competitiveness.

B. India: From Leakage Prevention to Inclusion Infrastructure

India's Aadhaar system was initially launched in 2009 to address welfare leakage, not economic participation. By assigning a unique biometric ID to over a billion individuals, Aadhaar helped eliminate duplicate and fraudulent "ghost" beneficiaries from welfare schemes, such as food subsidy programs (PDS) and rural employment initiatives (MGNREGA). However, its economic effects grew significantly once it was integrated into the digital financial ecosystem. The introduction of eKYC processes using Aadhaar enabled banks, telecom companies, and fintechs to onboard users at an 85% reduced cost (Pathrabe et al., n.d). This low-cost verification became the bedrock for subsequent DPI layers. These included the Unified Payments Interface (UPI), a real-time mobile payment system, and the Account Aggregator framework, a network for securely sharing financial data with user consent.

Crucially, policy choices have expanded Aadhaar's permissible uses beyond anti-leakage. Under the Aadhaar Authentication for Good Governance (Social Welfare, Innovation, Knowledge) Rules, 2020, the Union government may authorise Aadhaar authentication "in the interest of good governance… promoting ease of living… [and] enablement of innovation," on a voluntary basis and subject to a proposal and UIDAI review. In practice, this creates a governance pathway for new inclusion use-cases while preserving procedural safeguards (UIDAI, 2020).

Firm-side outcomes have followed. The Economic Survey (2023–24) notes e-KYC costs fell from about $12 to ~$0.06, turning days of paperwork into near-instant verification—materially improving customer acquisition economics for banks, NBFCs, insurers, and fintechs. DigiLocker now provides API-verifiable documents at national scale (about 510–520 million users as of Apr 2025) (PIB, 2025) , cutting vendor/employee onboarding time and fraud checks. On the credit rail, the Account Aggregator ecosystem facilitated ₹1.6–1.67 trillion of loan disbursal across roughly 18.9 million loan accounts in FY25, signalling that portable, consented data is flowing through to underwriting, especially for small-ticket and MSME segments. (Sahamati, 2025)

More recently, adoption has shifted toward multi-modal authentication to reduce failure points and widen access. UIDAI's push on face authentication (alongside fingerprint/iris/OTP) is framed explicitly as an access and convenience play; transactions using face authentication have scaled rapidly, with 193.6 million in July 2025 and integrations across welfare (NSAP), education (medical-college attendance) and recruitment (SSC/RRB) (Ministry of Electronics & IT, 2025). The official face-authentication playbook positions this modality as a way to expand both financial and non-financial service access where fingerprints/iris are unreliable. Together, this points to a policy-led arc from "stopping leakage" to broadening eligibility, convenience and choice in how people prove identity. Regulators have reinforced this shift: the RBI's June 12, 2025 KYC revisions formalised flexible onboarding modes (face-to-face, V-CIP, and non-face-to-face/OTP), further lowering drop-offs and compliance overhead for providers (Reserve Bank of India, 2016).

This rapid integration, however, was accompanied by significant controversy. Critics raised alarms over privacy vulnerabilities and the potential for state surveillance. They also pointed to instances where authentication failed, often due to worn fingerprints among manual laborers or unreliable rural mobile networks, which excluded legitimate beneficiaries from essential services (Khera, 2017). India's Supreme Court has intervened multiple times to delineate the legal boundaries of Aadhaar's use, underscoring the ongoing tension between its function as an economic enabler and the imperative to protect fundamental rights. Aadhaar also enabled consented data sharing (via DigiLocker and AA), and simplified access to credit, insurance, and business registration for small producers and gig workers (Dixit, 2023). However, uptake varies widely, and Aadhaar's full economic potential depends on how well it is integrated-securely and accountably -with services that expand opportunity, not just compliance.

C. Nigeria: Fragmentation as an Economic Brake

Nigeria's digital identity reforms were driven by longstanding inefficiencies in its identity ecosystem. Before 2007, at least 13 federal agencies and various states operated parallel biometric systems, leading to duplication, high costs, and fragmented service delivery (World Bank, 2020). In response, the National Identity Management Commission (NIMC) was established under the NIMC Act of 2007 to centralize identity management and assign every citizen a unique, verifiable National Identification Number (NIN). This reform aligned with broader national priorities under the Economic Recovery and Growth Plan (ERGP), including financial inclusion, public safety, digital transformation, and effective targeting of social welfare programmes (World Bank, 2020).

Despite this clear mandate, institutional fragmentation—the very problem the NIN was designed to solve—has hampered its implementation. The coexistence of multiple ID systems, such as the NIN, Bank Verification Number (BVN), and tax identifiers, has created confusion and compliance burdens that act as an economic brake. Nigeria's architecture is more centralised and, so far, less open: API access is cautiously licensed and recently tightened after data-leak concerns (Macdonald, 2024). This fragmentation imposes tangible costs: a small business owner may need to complete separate verification processes for a bank loan (using BVN), tax registration (using a Taxpayer Identification Number), and a government contract (using NIN), cumulatively adding weeks of delays and administrative burden. While the BVN has enabled smoother onboarding in banking, and the NIN is mandatory for public services, poor interoperability has diluted system-wide efficiency (World Bank, 2020). Recent efforts to integrate ID databases are promising, but a meaningful economic impact will require a unified, consent-driven identity backbone that is trusted across sectors.

3.3 Embedding Identity to Create New Digital Markets

In the most advanced digital states, identity infrastructure evolves beyond a tool for access and compliance to become a commercial platform in its own right. When identity is deeply and seamlessly embedded across both public and private sector ecosystems, it becomes a catalyst for entirely new business models and can even begin to decouple economic activity from physical geography.

A. Thailand: Federated Identity as a Commercial Accelerator

Thailand's National Digital ID (NDID) framework offers a more integrated, federated approach that deliberately contrasts with centralized, government-run models; a model that, while fostering private-sector innovation and trust, can also present challenges in achieving universal coverage and consistent standards across all participants. Unlike India's state-led, top-down approach, Thailand's model reflects a strategic choice to position the government as a convener and standard-setter, while leveraging the private sector's existing trust networks and distribution channels to drive adoption. Built as a platform of platforms, NDID allows users to verify themselves using one trusted provider (e.g., a bank) and securely share that verification across other sectors with their consent. Thailand's NDID has expanded its blockchain-based digital identity infrastructure, with registrations up 50% to 9.2 million since November 2022, which makes half the population eligible as the system prepares for verifiable credentials and a digital wallet (Hersey, 2023). As a result, this dramatically reduces repetitive KYC and compliance checks, enabling quicker onboarding of both consumers and SMEs across banking, telecom, and e-commerce.

B. Estonia and Singapore: Embedding ID to Decouple Commerce from Geography

In advanced digital states like Estonia and Singapore, identity systems are fully embedded into the market ecosystem. Singapore's MyInfo, for example, enables secure sharing of verified data to streamline eligibility checks for loans and licenses (GovTech Singapore, 2017). Estonia provides the most comprehensive example of this integration, where the national eID is not just an administrative tool but a commercial one, supporting digital signatures, contract execution, and near-instant company formation. In both cases, the economic payoff lies not just in efficiency but in the reduced friction of participation: entrepreneurs can register faster, build credit more easily, and operate across regulatory domains with lower overhead. The Estonian government estimates that e-ID contributes ~2% GDP per year in savings and dramatically increases citizen engagement, with one of the highest rates of tax payments worldwide (Apolitical, 2018).

More profoundly, Estonia's digital infrastructure demonstrates how DPI can decouple economic participation from geographic location. Estonia's e-Residency program has created an entirely new commercial paradigm: location-independent EU business operations. Estonia's e-Residency program offers entrepreneurs a unique opportunity to access the extensive European Union market without relocating. Establishing an Estonian company grants business owners entry to the EU's efficient system, facilitating the unrestricted movement of goods and services across its 27 member countries (Global Wealth Protection, 2025). By 2024, the program had attracted nearly 115,000 e-residents who have established over 28,000 Estonian companies (e-Residency, 2024).

This "digital by default" setup is the context in which several Estonian-founded firms scaled internationally. Companies like Wise (formerly TransferWise) (Ingham, 2021), and Bolt are Estonian-founded firms that have likely benefited from Estonia's advanced digital governance - e-ID, X-Road interoperability, and an online company register/e-residency that make incorporation, filings, and cross-border administration low-friction. That enabling environment lowers fixed costs for starting and running a business, shortens compliance cycles (e-signatures, digital filings), and improves trust in counterparties - conditions that can make it easier for founders to focus on product and scaling.[2]

Furthermore, with the highest number of startups per capita in the world as of 2022 (Startup Estonia, 2023) and a supportive environment of over 140 business angels, incubators, and accelerators, Estonia has become one of Europe's top startup destinations (Stofferis, 2024). By 2024, e-residents from 180 countries were conducting business through Estonia, proving that DPI can decouple economic participation from geographic location (e-Residency, n.d). Estonia demonstrates that small nations can compete globally not by their physical resources but by becoming digital commercial platforms that others can build upon.

C. *Summary*

The cases above reveal a clear pattern: the economic impact of digital identity is not inherent in the technology itself but is a function of its design and integration. In nascent ecosystems like Zambia's, the initial value lies in establishing basic visibility for millions of previously unrecognized individuals. In more complex environments like Nigeria and Brazil, the primary challenge and economic prize lie in overcoming institutional fragmentation to create a unified, low-friction environment for formal participation. Finally, in advanced models like Thailand's and Estonia's, identity infrastructure evolves from an administrative tool into a commercial platform, enabling new business models by becoming a trusted, reusable layer for verification and authentication across the entire economy. The strategic choice between centralized and federated models, and the commitment to embedding identity deeply into both public and private services, ultimately determines whether it becomes a catalyst for broad-based economic transformation. It is the foundational act of establishing digital trust and visibility. By making actors recognizable, it sets the stage for meaningful economic exchange, turning the abstract

[2] It is important to note that neither company is structurally built on Estonia's public rails. Wise is headquartered in London and operates on global banking and payments networks; Bolt's mobility stack relies primarily on private infrastructure (maps, payments, device networks, driver onboarding systems). However, Estonia's DPI and governance choices facilitated emergence and early scaling by reducing administrative drag and increasing institutional trust while commercial outcomes depended on independent factors such as founder quality, product-market fit, access to capital, and the broader EU market.

promise of participation into a tangible reality.

While identity infrastructure creates the foundation for market participation, it is payment systems that transform day-to-day economic activity. Unlike identity, whose impacts are often indirect and gradual, payment infrastructure immediately affects transaction costs, liquidity, and market reach. We now turn to examining how different countries have built and deployed digital payment rails, and with what economic consequences.

Beyond Efficiency: How DPI Creates Entirely New Markets

The most profound commercial impact of DPI is not just in optimizing existing processes, but in enabling business models that were previously impossible.

- Estonia's e-Residency created a new global market for "country-as-a-service," allowing entrepreneurs anywhere to establish and run a regulated EU company online. This attracts thousands of digital nomad, freelance, and Web3 businesses that would not exist otherwise.

This ability to create new markets, not just improve old ones, is a hallmark of a truly transformative economic infrastructure.

4. How Instant Payments are Reshaping Commerce

Payment systems are the circulatory system of any modern economy, determining not just who can transact, but at what speed, cost, and level of trust. While identity infrastructure provides market visibility by establishing who an individual or business is, payment infrastructure determines market accessibility - the ability to exchange value efficiently. This foundational layer directly affects liquidity for small businesses, the transaction costs that define which markets are viable, and the overall efficiency of the economy. The power of these systems, when designed as public infrastructure, is staggering: India's Unified Payments Interface (UPI) processes over 18.3 Billion transactions, as of June, 2025 (PIB, 2025); Brazil's Pix broke a new record 250.5 million transactions in single day in December of 2024 (PIB, 2024), and Thailand's PromptPay processed more than 2.1 billion transactions worth a total value of more than 4.2 trillion THB in August 2024 (Patel, 2025). These are not mere digitization efforts; they represent a fundamental restructuring of economic relationships.

What distinguishes these systems as "public infrastructure" is not state ownership, but a specific governance approach. Unlike closed, proprietary systems run by a single commercial entity, a DPI approach establishes an open, level playing field. It achieves this through shared technical standards, minimalist rules that foster innovation, and policies mandating fair access for all qualified participants. This model intentionally separates the competitive layer of services (where fintechs and banks innovate) from the cooperative layer of shared rails (the payment switch itself, which acts like a digital postal service, sorting and routing payments between different institutions). The state's role shifts from being a market participant to being the enforcer of the market's foundational rules, ensuring interoperability, low costs, and financial inclusion are non-negotiable design principles.

Digital payment infrastructure transforms commercial dynamics through three primary pathways. First, by providing instant settlement, these systems have modified cash flow: Brazil's Pix enabled 42% of small businesses to make it their primary payment method (Pimenta, 2022). Second, by radically reducing marginal transaction costs, they make previously uneconomical business models viable. Between FY 2017-18 and FY 2024-25, UPI experienced a compound annual growth rate of 114% in volume and 118% in value (Artha Global, 2025). Credit card transactions increased by 30%, while debit card transactions decreased by 13% (PwC, 2023). Third, by creating network effects, they have increased adoption.

The following cases reveal how these governance choices lead to vastly different commercial outcomes.

4.1 Unlocking Liquidity and Improving Cash Flow for Small Business

For small and medium-sized enterprises (SMEs), stable cash flow is essential for managing inventory, paying suppliers, and mitigating risk. Traditional payment systems impose a working capital burden by delaying settlement for several days. Real-time payment infrastructure obliterates this lag, providing instant access to funds. This technical feature fundamentally changes how businesses operate, manage inventory, and grow.

A. Brazil: Pix Boosting SME Liquidity and Forcing Market Competition

In Brazil, Pix was a response to deep-seated economic inefficiencies. It was launched in 2020 as part of the broader E-Digital Strategy (2018–2022), which explicitly reframed digital transformation from a tool for government efficiency into a macroeconomic lever for competitiveness, innovation, and productivity gains. Pix emerged as a flagship DPI intervention designed to directly reduce transaction costs and formalise economic activity (OECD, 2020). Unlike India's identity-first approach, Brazil's policymakers strategically sequenced Pix ahead of a new digital identity system to deliver immediate economic gains by leveraging existing assets like high mobile penetration, 80% banked population and established tax registries (Bianchi, 2025). Crucially, the Central Bank of Brazil leveraged its regulatory authority to mandate participation by all large financial institutions. This decisive action prevented incumbent banks from creating competing, fragmented systems. It guaranteed a universally interoperable network from day one, overcoming the collective action problem that often stalls such initiatives.

As a real-time, 24/7 payment system, Pix has become the dominant payment rail, reaching 76.4% of the country's 211 million population (Monteiro, 2025). Its impact on small businesses is transformative. Its impact on small businesses is transformative. A 2022 survey revealed Pix had become the primary payment method for 42% of small businesses (Pimenta, 2022). This liquidity improvement has enabled market vendors to replenish inventory daily rather than weekly.

The structural impact extends to e-commerce, where Pix has overtaken traditional methods. Its zero-lag settlement and low fees (averaging just 0.22% for businesses) Pix has also improved cash flow SME cash flow through instant payment on delivery, helping 11.9 million merchants access faster, cheaper, financial services (Centre for Digital Public Infrastructure, 2024). Additionally, SME participation in e-commerce rose from 8% pre-pix to 29% in 2023, indicating that Pix did not merely digitise existing firms but enabled new market entrants (ABComm, 2023). The Central Bank's role in mandating equal access ensured that even small fintechs could offer the same payment speed as major banks, fundamentally altering the competitive landscape.

B. Nigeria: A Market-Led DPI Anchored in Real-Time Payments

Nigeria's journey demonstrates how a reliable, real-time payment system can become the bedrock for a national innovation ecosystem. In 2012, Nigeria's banking consortium launched the NIBSS Instant Payment (NIP) system to modernize an economy hampered by cash dependency and slow banking. Its development was the culmination of a long-term vision, underpinned by reforms like the 2007 Payments Systems Vision 2020 and enablers like the Nigeria Uniform Bank Account Number (NUBAN) system, which created a single, reliable format for all bank accounts (Ironsi, 2022). The government's reinforced Cashless Nigeria Policy in 2023, which imposed strict cash withdrawal limits, further accelerated adoption (Pinheiro-Aina, 2023).

Today, NIP processed over 904 million in July 2024, which is 22% year on year jump from 743 million recorded in July 2023 (Akintaro, 2024). This effective, industry-led utility model offers a different path from the public-utility approach in India. While NIP's open APIs eventually fueled a fintech boom, its governance structure initially prioritized the interests of its member banks. This shaped its evolution on matters like fee structures and the speed of access for non-bank innovators. The certainty of instant transfers enabled the rise of five unicorns (Moniepoint, Flutterwave, OPay, Interswitch, and Andela) (Amokeoja, 2024), and contributed to a climate where the Nigerian fintech ecosystem secured over $2.1 billion in investments in 2024 (Onyekachi, 2024). According to Forbes, Lagos, the capital of Nigeria, witnessed a 11.6-fold increase in enterprise value and raised $158 million in funding for startups, placing the city as Africa's leading tech hub (Amokeoja, 2025).

According to a report by PwC, the emergence of e-commerce has enhanced fintech activities in Nigeria (PwC, 2020) Jumia, often referred to as the "Amazon of Africa," was founded in Nigeria in 2012 with the aim of building a comprehensive e-commerce ecosystem that integrates marketplace services, logistics infrastructure, and digital payment solutions (Palma, 2025). By addressing the unique delivery and infrastructure challenges of African markets, Jumia has become a key enabler of digital commerce across the continent. Jumia states that most online shoppers on its site prefer to pay using their mobile phones and through NIP gateways (PwC, 2020). Its success highlights both the vast potential and the inherent volatility of tech ventures and implications of NIP in emerging economies.

4.2 Reducing Transaction Costs to Formalise the Informal Economy

The viability of digital payments for micro-transactions hinges on marginal costs. In many economies, formal payment systems carry transaction fees of 2-3%, making them prohibitive for the low-margin commerce that defines the informal sector. By driving the marginal cost of a digital transaction to near-zero, payment DPIs remove this barrier, allowing millions of micro-merchants to enter the digital economy.

A. India: UPI's Zero-Cost Model for Mass Financial Inclusion

India's Unified Payments Interface (UPI), launched in 2016, is one of the world's most expansive digital payment infrastructures, which processed over 20 billion transactions in August 2025, which is a 34% increase from transactions in the same period last year (Dubey, 2025). A pivotal design choice made by the National Payments Corporation of India (NPCI), a unique, non-profit entity owned by India's banks but operating under the strategic direction of the Reserve Bank of India, was a zero-MDR (Merchant Discount Rate) policy. This policy eliminated the percentage fee that merchants typically pay to banks and payment processors for every digital transaction, a cost that often makes accepting digital payments unviable for small businesses.

The effect on India's vast informal economy has been profound. UPI is actively used by approximately 50 million merchants in India (Thakur, 2024). By 2025, person-to-merchant transactions are projected to account for 75% of all UPI transactions, highlighting a significant behavioral shift in what was once primarily a cash-based economy (Thakur, 2024). This stream of transaction data creates a verifiable financial history that serves as a reliable proxy for cash flow. However, the benefits have not been uniform, with disparities along gendered lines. For the nearly 200 million women in India who own smartphones, nearly one-third are economically active, which represents a vast, untapped market ready to thrive in the digital financial ecosystem (NPCI, 2024).

B. Thailand: PromptPay and State-Led Digital Formalisation

Thailand's PromptPay illustrates a different strategy for driving mass adoption. In 2016, the Bank of Thailand launched PromptPay as the primary channel for government-to-person (G2P) transfers, such as social welfare payments. The government used these welfare programs as a "digital wedge," requiring millions of citizens to link their national ID to a bank account via PromptPay to receive benefits. This policy created a large, active user base, providing a compelling incentive for merchants to adopt the system. The rollout was carefully sequenced. Initially launched for government welfare, PromptPay expanded in January 2017 to inter-bank credit transfers (World Bank Group, 2016). This phased approach allowed regulators to manage risk and build confidence progressively. It now offers diverse use cases like bill payments and e-donations across various payment types and channels.

The commercial impact has been significant. The system's success is reflected in the data: for money transfers under 5000 baht (152 USD), the average ticket size fell from 570 baht (17 USD) in January 2023 to 510 baht (15 USD) in December, signaling widespread adoption of Promptpay as a routine payment platform among individuals (Banchongduang, 2024). Building on this, the Bank of Thailand introduced PromptBiz, an infrastructure that integrates invoicing, payment, and tax data, allowing SMEs to automate processes and build credit credibility.

C. Cambodia: Blockchain Payments Unlocking Cross-Border Commerce

Cambodia's Bakong system demonstrates how innovative technology can reduce transaction costs. In Cambodia's heavily dollarised economy, managing transactions in both U.S. dollars and the local Riel created significant inefficiencies. Bakong, a platform using modern distributed ledger technology, enables seamless, instant transfers in either currency via a single QR code. In 2024, Bakong conducted 608 million transactions totalling $104.81 billion, which is 95% greater than in 2023 (Transfi, 2025).

Small retailers importing goods can now settle with suppliers instantly, avoiding 3-5 day delays. Over 4.5 million merchants now accept Bakong payments, driven by several strategic initiatives. Lower transaction fees compared to conventional payment systems, rapid settlement times, and enhanced interoperability have contributed to this widespread adoption (Cromley, 2025). Its successful cross-border trials signal its potential to create a more efficient regional trade environment.

4.3 Integrating Payments with Broader Services to Drive Competitiveness

The most durable commercial impacts of payment DPI emerge when it is deeply integrated into a broader ecosystem of digital public goods for identity, data sharing, and service delivery. This integration creates a multiplier effect, reducing systemic friction and enabling new levels of efficiency and innovation.

A. Singapore: Integrating Payments for Global Trade Competitiveness

Singapore's payment infrastructure exemplifies how an integrated DPI ecosystem can become a cornerstone of national economic strategy. Rather than just facilitating domestic retail, Singapore has focused on creating seamless, end-to-end digital workflows. In 2023, Singapore's PayNow witnessed widespread adoption, with 80% of businesses and individuals using it and transaction volume reaching SGD 5 billion (Norbr, 2024). Real-time transactions are projected to reach 392.94 million by 2025, with a 23.2% CAGR, underscoring PayNow's vital role in modernizing Singapore's payment system (Patel, 2025).

B. Rwanda: Integrated Digital Infrastructure Accelerating Business Formation

Rwanda's simultaneous deployment of the IremboGov public service portal and the GovPay payment platform provides a compelling model of integration. An entrepreneur can now register a business online in under a day, down from a multi-day, paper-based process. This radical reduction in startup friction has contributed to a 40% annual increase in formal business registrations since 2019 (Rwanda Development Board, 2023). The integrated approach creates a virtuous cycle: a newly formalized business immediately gains access to government tenders, digital tax filing, and formal banking services. This approach is recognized for significantly streamlining the procedures for starting and operating a business, removing bureaucratic hurdles that previously hindered entrepreneurship.

C. Zambia: Interoperable Payments as a Critical First Step

Zambia's journey highlights the limitations of a payment system developed without full DPI integration.

The National Financial Switch (NFS), introduced in 2019, successfully created interoperability between banks and mobile money platforms. By 2020, the NFS had processed approximately 12 million transactions valued at K8.0 billion. This represented a significant increase from 2019, with a 61% rise in volume and a 67% rise in value (Bank of Zambia, 2020). However, the NFS was designed more as a closed-loop industry "switch"—a system to route messages between existing players—than an open, programmable "platform" on which anyone could build. It lacks public APIs (Application Programming Interfaces)—standardized, open gateways that allow third-party software from innovators to securely connect and interact with the payment system (Africa Nenda, 2024, p. 12).

Zambia's fintech ecosystem has begun to flourish. There are now 25 active fintechs offering products ranging from pay-as-you-go energy and micro-insurance to SME payment aggregation and credit scoring (GSMA, 2024). Platforms like ZPOS are enabling informal businesses to build credit histories, bridging the gap between informality and financial access (GSMA, 2024). Innovation hubs such as BongoHive and Impact Hub Lusaka are nurturing startups with tools, networks, and early-stage funding. While a fintech ecosystem is emerging, its impact is constrained. Zambia's experience provides a vital lesson: payment interoperability is a necessary first step, but its full economic potential is unlocked only when it is architected as part of a comprehensive DPI ecosystem.

D. Summary

While technological and economic outcomes vary, a clear pattern of successful governance emerges. The transformative cases—Brazil, India, Singapore—were not the result of a passive, market-led approach. They were the product of intentional state action to shape the digital economy's foundational layer. Whether through a central bank mandate, a public-private utility, or a deeply integrated state agency, the common thread is a commitment to ensuring core infrastructure operates as an open, interoperable, and low-cost public good. This active stewardship of the digital commons is what unlocks broad-based innovation and ensures the benefits of digitalization are widely shared.

The evidence is clear: digital payment infrastructure is a powerful engine for economic transformation. It unlocks liquidity through instant settlement, drives down transaction costs, and boosts national competitiveness through service integration.

These payment systems do more than just move money; they create a constant stream of high-fidelity economic data. Every transaction generates a digital record, creating a foundational byproduct of the digital economy. This data is the raw material for building more inclusive credit scoring models, designing responsive insurance products, and creating personalized financial services. This creates the next critical challenge: unlocking the value of data while safeguarding individual privacy. The infrastructure designed to meet this need is the central focus of the next section.

5. Building Credit Markets with Verifiable Data

Data sharing infrastructure solves a fundamental economic problem: one party in a transaction often knows more than the other. In most exchanges, this incomplete information leads to credit rationing, risk premiums, and missed opportunities. Traditional solutions like credit bureaus suffer from limited coverage, high costs, and data silos, typically capturing only formal sector activities.

Digital data-sharing infrastructure offers a fundamentally different approach. Consent-based portability transforms data from institutional assets into user-controlled economic capital. For the user, this means data sharing becomes an explicit and transparent act, managed through simple, secure interfaces where permissions can be granted for a specific purpose and duration, and revoked at any time. This architecture of trust is the foundation upon which economic value is built. Standardized APIs (Application Programming Interfaces, which act like secure digital messengers that allow different software systems to communicate) dramatically reduce verification costs. Expanded data sources allow alternative indicators—utility payments, mobile transactions, e-commerce history to substitute for traditional credit histories.

The economic potential of data sharing is often unlocked when built upon other foundational layers of digital public infrastructure, meaning shared, society-wide digital systems like identity and payments. A secure and widely adopted digital identity system, for instance, provides a trusted mechanism for user authentication and consent. Likewise, real-time payment systems can generate rich, verifiable transaction data that gives data sharing its value. The most impactful data-sharing ecosystems do not exist in isolation; they leverage and amplify the capabilities of these underlying public utilities.

The economic impact is measurable. India's Account Aggregator framework has facilitated over 269 million consent-based data shares, reducing loan processing from days to minutes (Sahamati, 2025). In Brazil, digitalisation has expanded financial inclusion and visibility within the formal system. Accelerated by COVID-19 emergency aid, the launch of Pix and Open Finance doubled the number of individual account holders from 77.2 million in 2018 to 152 million in 2023, representing an increase of 97%, and corresponding to 87.7% of the adult population (OECD, 2024). This reflects a shift in user behaviour towards formal and digital financial channels. For business customers, the number rose from 3.4 million to 11.6 million – a notable growth among micro and small entrepreneurs (Banco Central Do Brasil, 2024). Estonia's X-Road-enabled data change across over 1,000 institutions and enterprises, extending its impact to around 52,000 organisation (Nortal, 2025).

The implications are profound. When street vendors can share transaction histories with lenders, or small manufacturers can instantly verify tax compliance, trust becomes affordable. Markets previously failed by information gaps—small business lending, agricultural insurance, gig economy services—become viable.

However, unlike payments where network effects drive adoption, data sharing requires careful governance. The same infrastructure enabling inclusion can enable predatory practices if poorly managed. The following cases illustrate how different design choices and market contexts lead to distinct economic outcomes—from expanding credit access for the underserved to fueling national innovation ecosystems.

5.1 Unlocking Access to Credit for Individuals and MSMEs

The most immediate and widespread commercial application of data-sharing infrastructure is to correct the information asymmetries that have long constrained credit markets for individuals and small businesses.

A. India

India's Account Aggregator (AA) framework demonstrates how a regulated, market-based model for data sharing can operate at massive scale. The framework's key innovation is its governance: instead of a single state platform, it licenses competing private companies as 'Account Aggregators' to act as trusted data fiduciaries. Operationalised in 2021, the AA system acts as a data-sharing layer for information like bank statements and tax data. AAs do not store data; they enable consensual, encrypted, real-time transfers. This addresses the challenge of exclusion for microenterprise owners and informal workers who could not easily prove their financial credibility. By replacing fragmented, paper-based verification with an instant digital method, the AA system lowers onboarding costs and shortens loan processing times from days to minutes.

The measurable impact on market efficiency has been significant. For lenders using the network, loan appraisal turnaround times have been reduced from weeks to under 48 hours for many MSMEs, with even 30 minutes in some cases (Business Line, 2025). This radical reduction in friction has had a direct effect on credit flows, enabling an estimated $16billion of loan disimbursements in 2025 alone (Business Line, 2025). Lenders can now underwrite loans based on real-time cash flow data from GST and bank statements, rather than relying solely on traditional collateral. This has improved liquidity and business continuity for many businesses (CredAble, 2025). This demonstrates a direct link between consent-based data sharing and the viability of lending to previously hard-to-assess market segments.

This process is critically dependent on an "architecture of trust" built into the system's governance. The success of frameworks like the Account Aggregator is not merely technological; it rests on a clear legal basis for user consent, strong data minimization principles (collecting only what is necessary), and transparent rules for data access and use. Without such guardrails, which provide users with meaningful control and clear avenues for redress, efforts to reduce information asymmetry can quickly devolve into mechanisms for surveillance or exploitation.

As of mid-2024, the framework enabled over 112 million cumulative consent-based data-sharing transactions, with over 2.2 billion accounts linked in total (Ministry of Finance, 2025), enabling use cases such as loan underwriting and lending to micro, small, and medium-sized enterprises (MSMEs).

B. Brazil

Brazil achieved a similar outcome by deeply integrating its data-sharing framework with other digital systems, creating a powerful ecosystem effect. The Open Finance framework, introduced in 2019, leveraged the wider digital ecosystem—particularly the Pix payment system and gov.br digital ID—to amplify credit access. By lowering the cost of credit underwriting, it helped smaller lenders compete. Around 2.8 million people are expected to join the financial system by 2028, with a predicted GDP boost by 280 billion BRL (Araujo, 2024). Pix reinforced these gains by generating new, verifiable transaction data, creating a positive feedback loop: more payments led to richer data, enabling better credit terms.

C. Nigeria

Nigeria's Open Banking framework illustrates a different evolutionary path, beginning with an industry-led initiative that was later formalized by state regulation. In 2017, industry stakeholders formed a foundation to develop common API standards before the framework was formalized by the Central Bank of Nigeria (CBN) in 2023 (Central Bank of Nigeria, 2023). It allows secure sharing of financial data between banks and licensed third-party providers. While still in its early stages, it has spurred a wave of API-based fintechs that provide aggregation services for lending and personal finance apps (Odumosu & Sossouvi, 2021). Nigeria also has 3,360 startups as of 2022, with around 481 operational tech startups collectively providing employment for about 19,000 individuals (Amokeoja, 2024). Additionally, between 2015 and 2022, a total of 383 Nigerian tech startups, especially in the fintech domain, successfully secured over $2 billion in funding, which is a record high (Amokeoja, 2024).

D. Thailand

Thailand approached the challenge from a B2B perspective with PromptBiz, an open digital infrastructure for transmitting trade and payment data. In response to a pandemic-induced decline in SME contribution to GDP (Theparat, 2021), PromptBiz was designed to help businesses digitise their processes. It creates a verifiable digital footprint that can help SMEs access finance by integrating with existing business and tax service platforms (Bank of Thailand, n.d.).

5.2 Catalyzing a High-Growth Innovation Ecosystem

While unlocking credit is a primary goal, a more profound economic impact emerges when data-sharing infrastructure evolves into a foundational layer for a national innovation economy, creating new commercial value rather than just optimizing existing markets.

A. Estonia

Estonia’s digital transformation was shaped by necessity after its 1991 independence. Faced with limited resources, a broken public administration, and a sparse population, leaders made a strategic choice to leapfrog legacy systems, supported by foundational laws on data protection and digital signatures. This culminated in X-Road, launched in 2001, a secure data exchange layer that connects different systems without storing information in one central place. Estonia built a standardised, reusable infrastructure operating securely over the public Internet, enabling seamless interoperability across the public and private sectors (Hirdaramani, 2024). By 2024, this approach enabled 100% of public services to go fully online (Kriisa, 2025).

The system's design directly catalyzed commercial innovation by treating government data as a reusable resource. By standardizing secure data exchange, the state dramatically lowered the transaction costs for private firms to build new services. This created an environment where startups could easily access and combine public datasets. In one analysis, the automation of data exchange via X-Road was estimated to save over 1345 years of working time annually (e-Estonia, n.d).

This digital ecosystem has fostered a remarkable startup environment. Between 2015 and 2021, venture capital investments in Estonian startups amounted to €2.6 billion. By Q3 2024, these startups had generated a turnover of €2.7 billion, a 10% increase over the previous year (Global Finance, 2023; Finevolution, 2025).

Estonia's open data approach through X-Road has created unexpected commercial value. Real estate developers access integrated datasets combining land registry, building permits, and demographic data to identify development opportunities in minutes rather than months.

5.3 Enhancing Personal Financial Management in Mature Economies

In mature economies where basic financial inclusion is widespread, the economic value of data-sharing infrastructure shifts from enabling market access to enhancing household financial management and capital allocation.

Singapore’s SGFinDex (Singapore Financial Data Exchange), launched in 2020, allows individuals to consolidate financial data from public and private sources. Built on Singpass, Singapore's national digital identity system, it enables secure, consent-based data sharing. SGFinDex addresses fragmented financial information, facilitating better budgeting and retirement readiness. While targeting individuals, it generates economic value by empowering better household-level capital allocation and creating a more efficient market for data-driven financial advisory services (Sgfindex, n.d).

5.4 A Cautionary Tale: The Limits of Infrastructure Without a Viable Business Model

The success of these systems, however, is not guaranteed by technical sophistication alone. South Korea's journey was motivated by a different imperative: improving government transparency. The Government 3.0 Initiative led to a national open data policy (Moon, 2021). One key outcome was Open Banking, introduced in 2019. Operating through a centralised API system, it gives third parties access to account data and payment initiation services. By September 2022, the number of registered users for Open Finance reached 54.8 million, showing a nearly fourfold increase from 14.2 million users in January 2022 (Fintech News, 2024). This significantly reduced costs for fintech companies. According to Banksalad, open finance APIs have reduced onboarding time by more than 90 per cent (Banksalad, 2021).

While South Korea's Open Banking spurred fintech growth, its subsequent MyData initiative offers a crucial lesson on market alignment. Launched in 2022, MyData is a government-led platform allowing individuals to consolidate their financial and non-financial data to access new services (Fintech News, 2024).

However, South Korea's MyData commercial struggles offer important lessons. Despite 69 companies becoming MyData providers, banks have lost over KRW 100 billion annually operating these services (Development Asia, 2024). The critical failure: while BigTech companies successfully monetized data services through targeted products and advertising, traditional banks couldn't translate data access into commercial value. The contrast with India's Account Aggregator success is instructive - AA focused on specific use cases like lending where data directly enables underwriting, while MyData attempted broad

data sharing without clear commercial applications. This demonstrates that data infrastructure without aligned business models and regulatory incentives fails to generate economic value, regardless of technical sophistication.

The contrast with India's Account Aggregator framework reveals a fundamental difference in governance philosophy and market design. India's central bank did not build the system; it created the rules for a new market. By licensing a competitive field of private Account Aggregator companies, it incentivized them to develop commercially viable products that solved specific pain points for lenders. MyData, in contrast, was implemented as a centralized utility that all players were mandated to connect to, without a dynamic intermediary layer competing to create value. This crucial distinction demonstrates that data infrastructure, no matter how technically sophisticated, fails to generate economic value if its governance model stifles the very commercial innovation it is meant to enable. It must be paired with business models and regulatory incentives that solve a tangible market problem.

Summary

The economic impacts of data-sharing infrastructure are diverse and depend heavily on design and context. As these cases demonstrate, success hinges on the governance choices that shape the market. The most direct benefit is correcting information imbalances in credit markets, as seen in India, Brazil, and Nigeria. However, the effectiveness of these systems is amplified when they are built on foundational digital infrastructure like identity and payments.

Sustained political commitment can transform data infrastructure into a bedrock for national innovation. Estonia’s journey shows how a resilient, decentralized architecture that makes public data securely reusable can lower the barriers to entry for private enterprise. Yet the contrasting experiences of India and South Korea reveal a critical insight: the state's role is paramount. A model where the government regulates a competitive market of private intermediaries — as seen in India — fosters commercially viable solutions more effectively than a top-down mandate.

Ultimately, the difference between a transformative public good and an underutilized platform lies not in technology itself, but in the careful alignment of that technology with specific economic problems, viable business models, and the incentives of the institutions it is meant to serve.

6. From Walled Gardens to Public Squares: The Future of Digital Commerce

Discovery infrastructure addresses the fundamental challenge of matching supply with demand. Even when parties can identify themselves, transact digitally, and share information, they still must find each other. In many markets, this creates massive inefficiencies—small retailers cannot reach distant customers, rural producers cannot access urban markets, and service providers cannot efficiently match with needs.

Traditional solutions—from physical marketplaces to platform businesses—often create new forms of extraction. E-commerce platforms solve discovery but capture significant rents through commissions. Physical aggregators add intermediation layers reducing producer margins. Information brokers create opacity preventing direct buyer-seller relationships.

Discovery infrastructure as DPI represents a paradigm shift away from privately-owned 'walled gardens' toward open, 'public square' protocols. Under this model, transactions are no longer mediated by a single platform that captures value through commissions and data control. Instead, these open networks, built on shared protocols—or common digital rules—separate the core functions of commerce. By unbundling discovery, logistics, and payments into interoperable layers, they foster competition and innovation on each layer. This changes the economic logic from rent extraction by a central aggregator to value creation distributed among many specialized service providers, fundamentally altering the terms of market participation.

The economics draw from platform and market design theory. Reduced search costs enable efficient matching, expanding market size. Unbundled services allow specialized competition rather than requiring integrated platforms. Competitive dynamics shift from winner-take-all to service-layer competition, distributing value more equitably.

When small producers become as discoverable as large ones, market geography and concentration may fundamentally shift. Early implementations suggest transformative potential, though adoption and governance challenges remain.

6.1 Enhancing Market Discovery

The cases in this section illustrate how governments and ecosystems are building new digital 'public squares' to solve the market's matching problem, creating open discovery layers for everything from retail goods and agricultural produce to the skills and training needed for the future economy.

A. India: Creating Level Playing Fields with Open Networks (ONDC & eNAM)

In 2022, India's Department for Promotion of Industry and Internal Trade (DPIIT) launched the Open Network for Digital Commerce (ONDC) to democratize e-commerce. ONDC creates an interoperable open network, where different applications and services can seamlessly communicate and work together. This breaks away from the conventional "platform-centric" model. By unbundling commerce, ONDC allows any seller app to transact with any buyer app, driving commission rates down to 3-5% and allowing innovation to occur independently at each layer of the commerce stack: logistics, payments, and discovery (The Economic Times, 2022). In this new model, multiple service providers (for cataloging, logistics, payments, etc.) can plug into a common protocol, creating a level playing field for small retailers, local businesses, and startups by lowering entry barriers.

To address structural problems in India's digital commerce landscape — where e-commerce penetration remains around 7-9% despite rapid digitalisation (ANI, 2025) — ONDC lowers barriers for small retailers who struggle to afford or access large platforms. ONDC allows these retailers to be digitally visible across multiple buyer-facing apps without needing to build their storefronts or pay high commissions. By mid-2024, the network had onboarded over 500,000 sellers, with more than 80,000 of them operating in the mobility sector, and was processing over 8.9 million transactions per month across more than 1,000 cities (IANS, 2024). While these figures represent a small fraction of India's overall e-commerce market, early participants—from small artisans to local *kirana* stores (small, family-owned neighbourhood shops)—report increased visibility and lower customer acquisition costs. However, the network faces significant challenges in altering consumer behaviour accustomed to the integrated convenience of dominant platforms and ensuring consistent service quality across a decentralized ecosystem.

By digitizing quality assaying and enabling remote bidding, eNAM eliminated the requirement for physical presence that previously restricted farmers. Furthermore, e-payments through eNAM witnessed substantial growth, with the number of transactions increasing from INR 274 in 2016-2017 to INR 14,923 in 2017-2018, and the volume of transactions surging from INR 129.44 Lakhs to INR 2,381.36 Lakhs respectively (Mahto and Patil, 2024). This trend reflects a shift towards cashless transactions and improved financial inclusivity within the agricultural sector. Yet, the platform's digital success in price discovery is often constrained by physical-world bottlenecks in logistics and quality assurance, highlighting the need for parallel, non-digital investments.

Just as eNAM's digital discovery requires efficient physical and financial logistics to complete a transaction, the full economic impact of DPI is often realised in its ability to streamline the *fulfilment* of existing commercial and regulatory processes. When infrastructure for identity, data exchange, and verifiable credentials is in place, it can radically reduce the time, cost, and complexity of doing business—unlocking productivity and improving competitiveness.

India's Goods and Services Tax Network (GSTN) exemplifies a specialized DPI for fulfillment and compliance. Before its implementation, tax compliance was fragmented across states, involving manual filing and high rates of evasion. GSTN created a unified digital backbone where e-invoicing is mandatory for businesses above a certain threshold. Its APIs allow enterprise software (ERPs) to integrate directly, automating compliance. The system's automatic invoice-matching feature has been critical in eliminating fake invoices and reducing tax evasion. Gross collections rose 9.4% in 2024-25 as compared to 2023-24, reaching a record of INR 22.08 Lakh Crore (PIB, 2025). Data also illustrates that the number of active GST taxpayers also rose to 1.51 crore (PIB, 2025).

B. Singapore: A Discovery Platform for the Skills Economy

In a rapidly changing economy, the ability to discover relevant skills and training opportunities is a critical economic function. Singapore's MySkillsFuture portal is a national DPI designed to solve this discovery challenge. It serves as a unified digital platform for citizens to explore career pathways, identify skills gaps, and find accredited training courses from a wide range of public and private providers.

By consolidating information on thousands of courses and providing tools for self-assessment and career planning, MySkillsFuture dramatically reduces the search costs associated with lifelong learning. It connects three key market actors: individuals seeking to upskill, training providers seeking students, and employers seeking talent with specific competencies. The platform integrates with national identity (Singpass) and a personal skills credit system, creating a seamless fulfillment process. This transforms skill development from a fragmented, hard-to-navigate market into a coherent ecosystem, functioning as a "public square" where the supply and demand for skills can meet efficiently.

6.3 Streamlining Economic Fulfilment

While discovery infrastructure connects buyers and sellers, it is fulfillment infrastructure that streamlines the high-friction 'last mile' of the transaction—the administrative, legal, and logistical processes required to finalize an economic exchange.

A. Brazil: Reducing Economic Friction with Unified Government Services (gov.br & Conecta)

While Pix reshaped how businesses transact, gov.br transformed how they interact with the state. Consolidated as Brazil's unified digital access and identity platform, gov.br achieved over 90% adult registration by 2024 and integrated more than 4,000 services into a single interface (Forbes, 2024). For producers, the platform became a key tool for reducing the administrative friction associated with business entry, compliance, and formalisation. By digitizing processes that once required in-person visits and extensive paperwork, gov.br lowered a significant barrier to entry. The platform gov.br enabled more than 680 million user transactions and estimated savings of almost 3 billion Brazilian reais (almost $600 million) for the public coffers (Perrone, 2023). As noted earlier, this digital streamlining was a key factor in the significant growth of formal SME registrations.

More tellingly, financial institutions and e-commerce platforms began integrating gov.br credentials for onboarding users—reducing the costs of 'Know Your Customer' (KYC) compliance, the mandatory process of verifying client identities, and speeding up account activation for vendors and service providers. This helped businesses formalise faster, access digital finance, and participate in broader commercial ecosystems. The gov.br platform also contributed to lowering compliance burdens. Through a single sign-on, firms could access tax systems, export registries, and labour portals—tasks that previously required navigating multiple agencies and paper-based systems. For foreign firms, gov.br simplified entry: 92 foreign companies completed digital registration via the platform between 2019–2022, up from just 21 in the previous three-year period (Agência Brasil, 2023).

Brazil's Conecta gov.br extends beyond citizen services to enable seamless business-to-government commerce. The platform's data exchange protocols allow automatic verification of vendor credentials across federal, state, and municipal systems. In integration with Pix and Caixa Tem, gov.br also acted as a formalisation funnel during the COVID-19 pandemic, when millions of informal workers received emergency support via digital wallets linked to government IDs. This accelerated financial inclusion and provided an entry point into tax-registered, digitally visible economic activity. By 2023, Brazil's unbanked population had dropped to 4.6 million, from 16.3 million in 2021 (Kotschwar & Colter, 2024), a transformation made possible not just by payments infrastructure but by interoperable identity and access layers.

B. *Singapore: Digitizing Cross-Border Trade Fulfilment with TradeTrust*

TradeTrust is a digital infrastructure that uses a blockchain—a secure, decentralized ledger—to enable the trusted and legally recognised exchange of trade documents across borders. Developed by Singapore's Infocomm Media Development Authority (IMDA) and officially launched in 2020, TradeTrust provides a framework that allows digital trade documents—such as bills of lading—to be digitally issued, verified, and transferred in a tamper-proof format. The system uses open standards to ensure that digital documents are legally valid and internationally recognised. The economic implications are substantial. By replacing paper-based bills of lading—which can take days to be physically couriered between parties—with verifiable digital equivalents, TradeTrust can cut document processing times from days to hours. This acceleration unlocks significant value in trade finance by reducing the time capital is tied up in transit. Furthermore, it mitigates the risk of fraud, which is estimated to cost the industry billions annually, and reduces administrative overheads for exporters and importers on a single transaction (World Trade Organization, 2022).

C. *Summary*

Discovery and fulfillment infrastructure addresses the final mile of economic exchange: matching supply with demand and streamlining transactions. Cases from India, Brazil, and Singapore illustrate a shift from proprietary 'walled gardens' to open 'public square' protocols that distribute value more equitably. This transformation has two complementary functions. Open networks like India's ONDC enhance market discovery, making hundreds of thousands of previously invisible producers findable across a national marketplace. Simultaneously, integrated platforms like Brazil's gov.br and Singapore's TradeTrust streamline economic fulfillment, radically reducing the administrative friction of business registration, compliance, and cross-border trade. Ultimately, this layer demonstrates that digital connection is only fully realized when paired with efficient real-world execution. The full potential of DPI is unlocked when it reduces friction not just in finding opportunities, but in seeing them through to completion.

The combinatorial power of this integrated stack is best seen through the lens of a small entrepreneur in India. First, Aadhaar (Identity) allows her to open a bank account instantly via eKYC. Next, a UPI (Payments) QR code on her storefront allows her to accept digital payments at zero cost, creating a verifiable transaction history. When she needs a loan to expand her inventory, the Account Aggregator (Data Sharing) framework lets her securely share this digital transaction history with a lender in minutes. Finally, she can list her expanded product line on ONDC (Discovery) to reach a nationwide customer base. For this entrepreneur, DPI is not four separate technologies; it is a single, seamless pathway from being an invisible, cash-only informal actor to a visible, investable, and nationally connected business.

7. The DPI Playbook: A Guide to Ecosystem Orchestration

The divergent pathways of Digital Public Infrastructure implementation globally—from rapid, population-scale adoption to stalled, niche projects—are not accidents of technology. They are the direct result of the presence or absence of a supportive ecosystem. This reveals that building effective DPI is not merely an engineering challenge; it is an act of ecosystem orchestration. Success hinges on the state's ability to navigate a dual role: that of a strategic builder of foundational enablers and a trusted steward of the new digital economy's rules. Understanding how governments manage this dual responsibility is the key to explaining why some DPI initiatives catalyze broad-based economic development while others fail to achieve their potential.

This stewardship model represents a deliberate third way, distinct from two historical alternatives. It is not the top-down, state-controlled model that can stifle innovation, nor is it the purely market-led model of "permissionless innovation" that often leads to private monopolies and digital divides. Instead, the DPI approach posits that the state's most effective role is to build the minimalist, open "public squares" of the digital economy—the shared protocols for identity, payments, and data—and then act as a fair referee for the vibrant private sector activity that takes place within them. This requires a sophisticated form of governance capable of fostering competition while ensuring inclusion.

Fulfilling this dual role requires a government to assemble three interconnected layers of prerequisites. The state's builder role focuses on ensuring the foundational digital prerequisites are in place: ubiquitous and affordable mobile internet, robust cybersecurity, high smartphone penetration, and broad-based programs to equip citizens and businesses with digital literacy.

As a steward, the state's role is often more critical, as it must craft and enforce the institutional prerequisites that build trust and predictability. These include flexible, forward-looking regulatory frameworks; public trust underpinned by the rule of law; robust legal safeguards for data protection and consumer rights; and proactive competition policies to ensure open protocols do not become dominated by new monopolies. The distinct institutional approaches taken by countries like India, Brazil, and Nigeria reveal just how critical—and politically charged—this stewardship can be. In Brazil, the Central Bank's direct mandate for Pix was a state-led disruption of a captured market, requiring immense regulatory authority to force compliance from incumbent banks (IMF, 2023). In India, the creation of the quasi-public NPCI was an institutional innovation that bypassed state inertia while co-opting the banking sector to achieve public policy goals (Cook and Raman, 2019). The lesson is that the stewardship role is not a neutral, technocratic function; it is an active, often contentious process of wrestling with vested interests to define the foundational rules of the digital economy.

Finally, these digital and institutional layers must be aimed at solving clear economic prerequisites to have a transformative impact. DPI must be designed to address significant, widely felt market frictions, such as high transaction costs or credit exclusion. It requires a critical mass of businesses and consumers to generate network effects. Crucially, it depends on the availability of essential complements—the parallel services needed to complete transactions. The constraints facing India's eNAM platform provide a stark illustration: the system excels at digital price discovery, but a digital match is economically meaningless without the parallel physical infrastructure of logistics, quality assaying, and warehouses to move goods from seller to buyer (Gautaum et al., 2022). The absence of these complements constrains the platform's impact from national to merely regional integration.

These prerequisites are not a simple checklist; they are a dynamic, interconnected system where digital access without institutional trust is ineffective, and institutional rules without a clear economic purpose fail to gain traction. The following country experiences demonstrate how the interplay between these elements shapes the ultimate economic outcome.

8. Pathways to Impact: Evidence from the Field

The country cases examined in this paper reflect distinct national strategies, revealing how DPI, when aligned with clear economic objectives, becomes a powerful tool for achieving those goals.

India's UPI provides a clear success case where the prerequisites converged. An aggressive 4G rollout and affordable smartphones created the digital foundation. The system's open protocols and the decisive, if controversial, zero-MDR policy then radically lowered entry barriers. However, this model is not without tension, as the zero-MDR policy raises questions about the long-term financial sustainability for private payment providers, creating an ongoing policy debate (Kochuveedan, 2025).

In contrast, Nigeria's NIP payment system illustrates the constraints of partial success. Despite achieving significant scale on the back of strong mobile penetration, its full potential has been limited by fragmented identity systems and inconsistent rural connectivity. The lesson is that even world-class payment infrastructure cannot achieve its full network effects without deep integration with other DPI layers and ubiquitous connectivity. Zambia's slower progress with its national ID system (INRIS) further highlights this dependency. Despite sound technical architecture, the rollout has been hampered by glaring gaps in the ecosystem: limited smartphone penetration, weak rural connectivity, and the lack of a compelling, high-volume "killer app"—like social welfare payments—to create a powerful incentive for mass enrollment .

Ultimately, the institutional roots of DPI success often predate the technology itself. Estonia's digital state was built on foundational investments in digital literacy and legal frameworks that began decades ago. Conversely, South Korea's technically sophisticated MyData initially struggled because critical institutional prerequisites—namely, addressing incumbent resistance and fostering genuine competitive pressure—were not adequately met (Development Asia, 2024). This demonstrates a sobering lesson: lasting success is built on a foundation of long-term institutional capacity.

9. The Other Side of the Ledger: Managing Risks and Unintended Consequences

A focus on prerequisites must be balanced with a clear-eyed assessment of the inherent risks. If not governed by robust legal and ethical frameworks, centralized digital identity and data exchange systems can become tools for state surveillance and social control. The digital divide also creates a new frontier of exclusion, where those lacking devices, connectivity, or literacy are shut out of essential services, amplifying existing inequalities.

Furthermore, the transition to digital compliance, even when successful at a macro level, can create significant new frictions for the most vulnerable. The rollout of India's GSTN, for example, illustrates this "compliance trap." While it streamlined processes for established firms, it simultaneously imposed heavy burdens on micro-enterprises, which struggled with the cost and complexity of digital tools, the need for reliable internet access, and the new regulatory scrutiny (Mishra, 2025). If formalization exposes small businesses to tax or regulatory burdens they are not equipped to handle, it can push them deeper into the shadows rather than integrating them. This demonstrates that the real-world success of such initiatives often requires years of iteration, feedback from small business communities, and adjustments to regulatory thresholds to achieve a balance between formalization and enterprise viability.

A more subtle, second-order exclusion can also emerge: an informal worker may gain access to a bank account via a digital ID but still be denied credit because their newly visible transaction data does not fit the rigid risk-assessment algorithms of formal lenders. This highlights the need for policies that promote not just technical access but genuine economic inclusion.

Beyond individual risks, the deep integration of DPI creates systemic economic risks. As national economies become dependent on a single instant payment switch or identity system, any technical failure or cyberattack can have catastrophic, cascading consequences. Nigeria's economy has experienced this directly, where periodic outages of its central payment switch have frozen digital economic activity for hours at a time (Monye, 2024). This underscores the absolute necessity of investing in resilience, redundancy, and robust security for what has become critical national infrastructure. These outcomes are not predetermined by technology; they are shaped by governance choices around data minimization, architectural design, and legal oversight, highlighting the primacy of democratic accountability in the digital age.

Summary

The divergent outcomes detailed above are therefore not surprising; they are the predictable results of the presence or absence of a supportive ecosystem. Where digital, institutional, and economic prerequisites converged, as with India's UPI, the impact has been exponential. Where one or more of these pillars were weak—be it Nigeria's fragmented identity systems, Zambia's connectivity gaps, or South Korea's institutional inertia—even sophisticated technology struggled to deliver on its full potential. The evidence confirms that technology alone is a passive ingredient; it is the active, and often difficult, work of statecraft that transforms digital infrastructure from a mere technical upgrade into a true engine for economic change. The state's role as an ecosystem orchestrator is therefore not just important, but paramount.

Furthermore, this analysis reveals that success is not a static destination but a constant balancing act. The very power that makes DPI a tool for inclusion also presents profound governance challenges, from the risks of surveillance and new digital divides to the imposition of "compliance traps" on the most vulnerable businesses. The economic dependency on a single payment switch, as seen in Nigeria, creates new systemic vulnerabilities that demand investment in resilience. Ultimately, this highlights that the line between an empowering public good and a tool for exclusion is drawn not by technology, but by deliberate governance choices. The ongoing debates around data protection, algorithmic bias, and the financial sustainability of these systems are not peripheral concerns; they are central to ensuring that DPI rewrites the rules of commerce for the many, not just the few.

10. Conclusion

This paper has moved beyond the principles of Digital Public Infrastructure to document its real-world economic consequences. By examining how DPI interacts with production structures on the ground, a clear picture emerges: when strategically designed and deployed, DPI can fundamentally change the economic terms of participation for firms, entrepreneurs, and workers. The scale of this transformation is captured in stark numbers:

- **Transaction Cost Reduction:** KYC costs in India dropped from Rs. 1000 to Rs. 6 (MoneyControl, 2024), transaction fees for merchants using Brazil's Pix averaging just 0.33%, a fraction of the 2-3% typical for credit card payments (IMF, 2023), and **Market Expansion:** Over 500 million new merchants brought into the digital payments ecosystem in India, hundreds of thousands of previously invisible sellers made discoverable through ONDC.

- **Economic Value Creation:** India's UPI processing transactions worth nearly $2 trillion annually (European Payments Council, 2024), Estonia's e-Residency program contributing an estimated €342 Million in direct economic impact and company turnover, (Invest Estonia, 2025), and Nigeria's payment rails anchoring a fintech ecosystem that attracted over $2 billion in investment (Bitke, 2024).

- **Productivity and Time Savings:** Estonia's digital signatures saving an estimated 1345 working years annually (e-estonia, n.d),, and loan processing in India cut from weeks to minutes.

Yet, these successes are not the result of technology alone. They are the product of intentional statecraft. Where digital prerequisites like connectivity and devices, institutional prerequisites like smart regulation and trust, and economic prerequisites like clear market pain points aligned, DPI achieved exponential impact. Where these elements were absent, even technically sophisticated systems struggled to gain traction or deliver widespread benefits. The central lesson is that building effective DPI is not merely an engineering challenge; it is an act of ecosystem orchestration.

To understand the full scope of its potential, DPI should be situated within the broader history of transformative digital technologies. We can find lower-bound analogues for its economic impact in the history of Free and Open-Source Software (FOSS) and Software-as-a-Service (SaaS). FOSS, like the Linux kernel or Apache web server, provided foundational, non-proprietary rails upon which a trillion-dollar web economy was built. Similarly, SaaS platforms like Stripe or AWS abstracted away immense complexity, allowing startups to access world-class infrastructure for payments and computing at a variable cost. Both demonstrate how a low-cost, reusable, and interoperable layer can unleash waves of commercial innovation by lowering the barriers to entry.

References

Agência Brasil. (2022, April). Gov.br platform boosts the opening of branches of foreign companies in Brazil. Serviços e Informações do Brasil. https://www.gov.br/en/government-of-brazil/latest-news/2022/gov-br-platform-boosts-the-opening-of-branches-of-foreign-companies-in-brazil

Akintaro, S. (2024, September 25). Nibss: E-payment transactions in Nigeria hit N89.5 trillion in July 2024, Highest Monthly record. *Nairametrics*. https://nairametrics.com/2024/09/25/nibss-e-payment-transactions-in-nigeria-hit-n89-5-trillion-in-july-2024-highest-monthly-record/

Alston, P. (2019, October 11). Report of the Special Rapporteur on extreme poverty and human rights (A/74/493). United Nations General Assembly. https://www.undocs.org/A/74/493

Amokeoja, O. (2024). Accelerating startup growth: Nigeria's incubators. *Forbes Africa*. https://www.forbesafrica.com/entrepreneurs/2023/10/31/accelerating-startup-growth-nigerias-incubators

Amokeoja, O. (2024, December 24). The African Tech Unicorns leading the way towards an innovative future. *Forbes Africa*. https://www.forbesafrica.com/current-affairs/2024/12/24/the-african-tech-unicorns-leading-the-way-towards-an-innovative-future

Amokeoja, O. (2025, May 23). Home to unicorns, Lagos tops global tech rankings. *Forbes Africa*. https://www.forbesafrica.com/current-affairs/2025/05/23/home-to-unicorns-lagos-tops-global-tech-rankings/

ANI. (2025, July 28). Only 20-25% of India's 850 MN internet users shop online, shows untapped potential: McKinsey Report. *The Economic Times*. https://economictimes.indiatimes.com/industry/services/retail/only-20-25-of-indias-850-mn-internet-users-shop-online-shows-untapped-potential-mckinsey-report/articleshow/122944287.cms

Apolitical. (2018). e-ID saves Estonia 2% of GDP a year. It's time America caught up. https://apolitical.co/solution-articles/en/e-id-in-america

Araujo, M. L. (2024, October 23). Pix Deve Impulsionar Pib do Brasil em R$ 280,7 Bilhões Até 2028, Aponta Estudo. *CNN Brasil*. https://www.cnnbrasil.com.br/economia/macroeconomia/pix-deve-impulsionar-pib-do-brasil-em-r-2807-bilhoes-ate-2028-aponta-estudo/

Artha Global. (2025). *Understanding UPI through User Experience: Insights from the Ground*. Artha Global. https://artha.global/wp-content/uploads/2025/09/Understanding-UPI-Report_FINAL.pdf

Banchongduang, S. (2024). PromptPay usage hits record high in 2023. *Bangkok Post*. https://www.bangkokpost.com/business/general/2775166/promptpay-usage-hits-record-high-in-2023

Banco Central Do Brasil. (2024). *Annual Report 2024*. https://www.bcb.gov.br/content/publications/Annual_Report_docs/AR-2024.pdf

Bank of Thailand. (n.d.). *Promptbiz*. https://www.bot.or.th/en/financial-innovation/digital-finance/digital-payment/promptbiz.html

Bank of Zambia. (2020). *National Payment Systems in Zambia 2020*. Bank of Zambia. https://www.boz.zm/payment-systems-annual-reports.htm

Banksalad. (2021, December 1). BankSalad Launches Pilot Service with MyData API. https://corp.banksalad.com/news/마이데이터_API_적용/

Bianchi, T. (2025). Topic: Internet usage in Brazil. *Statista*. https://www.statista.com/topics/2045/internet-usage-in-brazil/

Bitke. (2024, December 16). Report: Nigerian Fintech received over $2 billion in investments in 2024, says government. *BitKE*. https://bitcoinke.io/2024/12/nigerian-fintech-investments-in-2024/

Brown, H. (2022, June 13). Digital Growth Gateway Estonia sets record for company incorporation. *Republic of Estonia e-Residency*. https://www.e-resident.gov.ee/blog/posts/estonian-e-resident-breaks-speed-record-for-company-incorporation/

Business Line. (2025, September 2). Account aggregators enable ₹1.6 lakh crore loan disbursement in 2025, says industry body. *BusinessLine*. https://www.thehindubusinessline.com/money-and-banking/account-aggregators-enable-16-lakh-crore-loan-disbursement-in-2025-says-industry-body/article70004463.ece

Central Bank of Nigeria. (2023). *Issues the operational guidelines for open banking*. https://www.cbn.gov.ng/Out/2023/CCD/Operational%20Guidelines%20for%20Open%20Banking%20in%20Nigeria.pdf

Centre for Digital Public Infrastructure. (2024). *DPI for open finance - A case study on UPI & PIX*. https://cdpi.dev/wp-content/uploads/2024/09/DPI-for-Open-Finance-A-case-study-on-UPI-Pix-1.pdf

Centre for Digital Public Infrastructure & Smart Zambia Institute. (2024). *Against All Odds: Zambia's Journey to Digital Transformation – CDPI*. Centre for Digital Public Infrastructure. https://cdpi.dev/zambia-digital-transformation/

Chang, R., & Malik, T. (2024). DPI safeguards come online in Zambia's next phase of digital integration. *UNDP*. https://www.undp.org/digital/blog/dpi-safeguards-come-online-zambias-next-phase-digital-integration

Coase, R. H. (1937). The nature of the firm. *Economica*, *4*(16), 386–405. https://doi.org/10.1111/j.1468-0335.1937.tb00002.x

Cook, W., & Raman, A. (2019, May). *National Payments Corporation of India and the Remaking of Payments in India*. CGAP. https://www.cgap.org/sites/default/files/publications/2019_05_07_NPCI_Working_Paper_0.pdf

CredAble. (2025, May 21). Digital Lending in India: Replacing credit scores with real-time SME Risk Models. *Credable*. https://credable.in/insights-by-credable/business-insights/digital-lending-guidelines/

Cromley, K. (2025, March 25). Cambodia's Bakong platform sees massive growth in payment volumes. *CoinTrust*. https://www.cointrust.com/market-news/cambodias-bakong-platform-sees-massive-growth-in-payment-volumes

Dadi, S. (2024). Inclusion in Ethiopia's ID system opens new doors for refugees. *UNHCR*.

https://www.unhcr.org/in/news/stories/inclusion-ethiopia-s-id-system-opens-new-doors-refugees

Development Asia. (2024, November 20). Transforming the Republic of Korea's banking industry through MyData 2.0. https://development.asia/insight/transforming-republic-koreas-banking-industry-through-mydata-20

Dixit, S. (2023). India's digital transformation could be a game-changer for economic development. *World Bank Blogs.* https://blogs.worldbank.org/en/developmenttalk/indias-digital-transformation-could-be-game-changer-economic-development

Dubey, N. (2025, September 2). UPI Transactions jump 34% in August 2025, Cross 20 billion mark. *Angel One - Share Market Trading.* https://www.angelone.in/news/market-updates/upi-transactions-jump-34-percent-in-august-2025-cross-20-billion-mark

e-Estonia. (2025). *X-road - e-estonia.* https://e-estonia.com/solutions/interoperability-services/x-road/

e-Residency. (n.d.). How many Estonian e-residents are there? Find e-residency statistics. *Republic of Estonia e-Residency*. https://www.e-resident.gov.ee/dashboard/

Eaves, D., & Sandman, J. (2023, December 20). What is Digital Public Infrastructure? *Co-Develop.* https://www.codevelop.fund/insights-1/what-is-digital-public-infrastructure

European Payments Council. (2024, June 26). UPI: Revolutionising real-time digital payments in India. *European Payments Council.* https://www.europeanpaymentscouncil.eu/news-insights/insight/upi-revolutionising-real-time-digital-payments-india

Finevolution. (2025, January 15). Estonia: Europe's fastest-growing hub for Unicorns. https://finevolution.pl/en/post/estonia-the-place-where-unicorns-are-born/

Fintech News. (2024, June 19). Open banking success in South Korea could be a blueprint for the rest of Asia. *Fintech Hong Kong.* https://fintechnews.hk/29161/fintechkorea/open-banking-korea/

Global Finance. (2023). Estonia GDP and Economic Data. *Global Finance Magazine.* https://gfmag.com/country/estonia-gdp-country-report/

Global Wealth Protection. (2025). *Estonia's e-Residency program: a gateway for Location-Independent entrepreneurs.* https://globalwealthprotection.com/estonia-e-residency-program-a-gateway-for-location-independent-entrepreneurs/

GovTech Intelligence Hub. (2025). *Conecta gov.br: Brazil's National Interoperability Platform for Automated Data Exchange.* https://www.govtechintelhub.org/case-study-details/conecta-gov.br:-brazil's-national-interoperability-platform-for-automated-data-exchange/aJYTG0000000YxI4AE

GovTech Singapore. (2017). Businesses can tap on MyInfo to offer faster transactions for citizens. *Government Technology Agency of Singapore (GovTech Singapore).* https://www.tech.gov.sg/media/businesses-can-tap-on-myinfo

GSMA. (2024). *Driving Digitalisation of the Economy in Zambia Leveraging policy reforms.* https://www.gsma.com/about-us/regions/sub-saharan-africa/wp-content/uploads/2024/10/GSMA_Zam bia-Report_Oct-2024_Final.pdf

Hersey, F. (2023). Thailand's blockchain digital ID infrastructure – an ecosystem in an ID ecosystem. *Biometric Update*. https://www.biometricupdate.com/202303/thailands-blockchain-digital-id-infrastructure-an-ecosystem-in-an-id-ecosystem

Hirdaramani, Y. (2024, March 21). Estonia's X-Road: Data Exchange in the world's Most Digital Society. *GovInsider*. https://govinsider.asia/intl-en/article/estonias-x-road-data-exchange-in-the-worlds-most-digital-society

IANS. (2024, June 3). ONDC clocks all-time high of 8.9 million transactions in May. *ETRetail.com*. https://retail.economictimes.indiatimes.com/news/e-commerce/e-tailing/ondc-clocks-all-time-high-of-8-9-million-transactions-in-may/110671211

ID Tech. (2025, May 22). Ethiopia launches Fayda Digital ID System to cover 90 million citizens by 2027. https://idtechwire.com/ethiopia-launches-fayda-digital-id-system-to-cover-90-million-citizens-by-2027/

Ingham, L. (2021). Wise's Estonian origins. *FXC Intelligence*. https://www.fxcintel.com/research/analysis/wises-estonian-origins

International Monetary Fund. Western Hemisphere Dept. (2023). *Pix: Brazil's Successful Instant Payment System*. IMF Staff Country Reports, *2023*(289), A004. https://doi.org/10.5089/9798400249266.002.A004

Invest Estonia. (2025a, August 21). E-residency brings record revenue in first half of 2025. *Invest in Estonia*. http://investinestonia.com/e-residency-brings-record-revenue-in-first-half-of-2025/

Ironsi, T. (2022). How NIBSS Instant Payment (NIP) powers Nigeria's Digital Economy. *Paystack*. https://paystack.com/blog/operations/nibss-instant-payments-nip

Khera, R. (2017). Impact of Aadhaar on welfare programmes. *Economic and Political Weekly*, *52*(50), 39–49. https://www.epw.in/journal/2017/50/commentary/impact-aadhaar-welfare-programmes.html

Kochuveedan, B. (2025, August 6). UPI isn't free even now, someone covering the cost already: RBI governor Malhotra. *The New Indian Express*. https://www.newindianexpress.com/business/2025/Aug/06/upi-isnt-free-even-now-someone-covering-the-cost-already-rbi-governor-malhotra

Kotschwar, B., & Colter, C. (2024, October 25). *Global DPI models: Lessons from India, Brazil, and beyond*. Atlantic Council. https://www.atlanticcouncil.org/in-depth-research-reports/issue-brief/global-dpi-models-lessons-from-india-brazil-and-beyond/

Kriisa, K. (2025, January 27). Estonia: 100% Digital Government Services. *e-Estonia*. https://e-estonia.com/estonia-100-digital-government-services/

Macdonald, A. (2024, April 2). World bank says Nigeria on track to meet digital ID registration target. *Biometric Update*. https://www.biometricupdate.com/202404/world-bank-says-nigeria-on-track-to-meet-digital-id-registration-target

Mahto, R. K., & Patil, C. (2024). Digital Transformation in Agricultural Marketing: Analyzing the Progress of e-NAM in Haryana, India. *Mysore Journal of Agricultural Sciences*, *59*(1), 310–320.

Mari, A. (2024, March 4). Brazil has the world's Most accessed online citizen services platform. *Forbes*. https://www.forbes.com/sites/angelicamarideoliveira/2024/03/04/brazil-has-the-worlds-most-accessed-online-citizen-services-platform/

Ministry of Electronics & IT. (2025). *Aadhaar Face Authentication recorded an all time high with 19.36 crore transactions in July 2025* [Press release]. https://uidai.gov.in/images/Press_Release-_16.pdf

Ministry of Electronics and IT. (2024). *Aadhaar: a unique identity for the people*. Press Information Bureau. https://www.pib.gov.in/PressReleasePage.aspx?PRID=2067940

Ministry of Finance. (2025, September 2). Celebrating four years of launch of the account aggregator ecosystem - India's Digital Public Infrastructure (DPI). *Press Information Bureau*. https://www.pib.gov.in/PressReleasePage.aspx?PRID=2162953

Mishra, M. (2025, July). GST@8: India's tax landscape has changed but key reforms are still pending. *Grant Thornton Bharat*. https://www.grantthornton.in/insights/articles/gst-8-indias-tax-landscape-has-changed-but-key-reforms-are-still-pending/

MoneyControl. (2024, July 22). E-KYC cost down from rs 1,000 to less than Rs 6: Economic survey 2024. *Moneycontrol*. https://www.moneycontrol.com/technology/e-kyc-cost-down-from-rs-1000-to-less-than-rs-6-economic-survey-2024-article-12774537.html

Monteiro, T. (2025a, July 2). Pix becomes Brazil's top transaction method. *Global Finance Magazine*. https://gfmag.com/transaction-banking/pix-becomes-brazils-top-transaction-method/

Monye, E. (2024, January 18). Why Nigeria's controversial naira redesign policy hasn't met its objectives. *Carnegie Endowment for International Peace*. https://carnegieendowment.org/research/2024/01/why-nigerias-controversial-naira-redesign-policy-hasnt-met-its-objectives?lang=en

Moon, J. (2021). *Enhancing Transparency and Quality of Public Services: The Republic of Korea's Open Data Policy*. Global Delivery Initiative. https://www.effectivecooperation.org/system/files/2021-06/gdi_case_study_korea_open_data.pdf

Norbr. (2024, July 4). Payment methods in Singapore. *NORBr*. https://norbr.com/library/payworldtour/payment-methods-in-singapore/

Nortal. (2025). Why Digital Sovereignty Matters and how X-road makes it happen. https://nortal.com/insights/why-digital-sovereignty-matters-and-how-x-road-makes-it-happen

NPCI. (2024, September 10). UPI for her: Unlocking the power of 200 million women in India's Digital Payments Revolution. *Women's World Banking*. https://www.womensworldbanking.org/insights/upi-for-her-unlocking-the-power-of-200-million-women-in-indias-digital-payments-revolution/

Odumosu, A. O., & Sossouvi, K. (2021, May). *Building Resilience Through Digital Financial Services*. International Financial Corporation. https://www.ifc.org/content/dam/ifc/doc/mgrt/nigeria-building-resilience-through-dfs.pdf

OECD. (2020). *Going Digital in Brazil (EN)*.

https://www.oecd.org/content/dam/oecd/en/publications/reports/2020/10/going-digital-in-brazil_532cb108/e9bf7f8a-en.pdf

OECD. (2024, September). *Competition, Fintechs and Open Banking Brief Considerations on the Market and the Performance of CADE.* https://one.oecd.org/document/DAF/COMP/LACCF(2024)4/en/pdf

Onyekachi, N. (2024, December 7). Nigeria's fintech system attracted over $2 billion in investments in 2024 – FG's economic report. *Nairametrics.* https://nairametrics.com/2024/12/07/nigerias-fintech-system-attracted-over-2-billion-in-investments-in-2024-fgs-economic-report/

Palma, G. (2025, August 4). African unicorns: The billion-dollar startups of Nigeria, Kenya, South Africa, Egypt, and beyond. *Tech News 180.* https://technews180.com/unicorns-soonicorns/african-unicorns/

Patel, A. (2025, April). PromptPay: Reshaping Thailand's financial landscape. *Juspay.* https://juspay.io/en-sg/blog/promptpay-reshaping-thailand-s-financial-landscape

Pathrabe, P., Lele, S., Kar, N., & Rodrigues, M. L. (n.d.). Balancing privacy and benefits. *PwC.* https://www.pwc.in/industries/financial-services/fintech/fintech-insights/balancing-privacy-and-benefits.html

Perrone, C. (2023, November 15). *Brazil's bridges to the future: How the country is Building Digital Infrastructure.* Carnegie Endowment for International Peace. https://carnegieendowment.org/posts/2023/11/brazils-bridges-to-the-future-how-the-country-is-building-digital-infrastructure?lang=en

PIB. (2025). *The Digital Decade: India's Journey Towards a Tech-Led Future.* https://static.pib.gov.in/WriteReadData/specificdocs/documents/2025/jun/doc2025612568801.pdf

PIB. (2025, July 20). *India's UPI Revolution.* Press Information Bureau, Government of India. https://www.pib.gov.in/PressNoteDetails.aspx?NoteId=154912&ModuleId=3

PIB. (2025, June 30). Record gross GST collection in 2024–25. *Press Information Bureau.* https://www.pib.gov.in/PressNoteDetails.aspx?id=154789&NoteId=154789&ModuleId=3

Pimenta, G. (2022, October 19). PIX is main mean of payment used by small businesses. *Valor International.* https://valorinternacional.globo.com/business/news/2022/10/18/pix-is-main-mean-of-payment-used-by-small-businesses.ghtml

Pinheiro-Aina, A. (2024, March 5). Nigeria's Digital Economy: Building a digital payments ecosystem. *FXC Intelligence.* https://www.fxcintel.com/research/reports/nigerias-digital-economy-building-digital-payments-ecosystem

Pizzolato Gonçalves, B., & Venijio Maggion, R. (2022). Benefícios econômicos da transformação digital de serviços públicos: o caso da cidade de São Paulo. In *BID.* https://publications.iadb.org/es/beneficios-economicos-de-la-transformacion-digital-de-los-servicios-publicos-el-caso-de-la-ciudad

PwC. (2020). *Changing Competitive Landscape: Fintech and the Banking Sector in Nigeria.* https://www.pwc.com/ng/en/assets/pdf/fintech-banking-sector-nigeria.pdf

PwC. (2023). *The Indian Payments Handbook – 2023–2028.* https://www.pwc.in/assets/pdfs/consulting/financial-services/fintech/publications/the-indian-payments-handbook–2023–2028.pdf

Reserve Bank of India. (2016). https://www.rbi.org.in/commonman/English/scripts/notification.aspx?id=2607

Sahamati. (2024). Account Aggregators to foster Investment Advisory Services in India. https://sahamati.org.in/account-aggregators-to-foster-advisory-services-in-india/

Sahamati. (2025, September 29). Sahamati Marks 4th Account Aggregator Foundation Day, India's Data Empowerment Revolution Scales New Heights. https://sahamati.org.in/sahamati-marks-4th-account-aggregator-foundation-day-indias-data-empowerment-revolution-scales-new-heights/

Sandeep Gautam, Supriya, Srivastava, A. B., & Bohra, D. (2022). Factors Constraining Farmer's Adoption of the E-National Agriculture Market (eNAM) in Sultanpur District of Uttar Pradesh. *Asian Journal of Agricultural Extension, Economics & Sociology*, *40*(12), 501–506. https://doi.org/10.9734/ajaees/2022/v40i121830

SGFinDex. (n.d.). *SGFinDex*. https://www.sgfindex.gov.sg/

Startup Estonia. (2023, February 17). Chapter 2022 of the Estonian Startup Sector - the test of resilience. https://startupestonia.ee/statistics-surveys/chapter-2022-of-the-estonian-startup-sector-the-test-of-resilience/

Stofferis, A. (2024, April 9). The rise of Estonia's startup ecosystem. *Republic of Estonia e-Residency*. https://www.e-resident.gov.ee/blog/posts/the-rise-of-estonias-startup-ecosystem/

Thakur, D. C. (2024, May 18). Age of UPI: What's next in the Horizon. *Economic Times*. https://bfsi.economictimes.indiatimes.com/blog/age-of-upi-whats-next-in-the-horizon/110217051

The Economic Times. (2022). The A to Z of ONDC's commission structure. *The Economic Times*. https://economictimes.indiatimes.com/tech/technology/the-a-to-z-of-ondcs-commission-structure/articleshow/93970529.cms

Theparat, C. (2021, July 1). Contribution of smes to GDP to drop. *Bangkok Post*. https://www.bangkokpost.com/business/general/2143935/contribution-of-smes-to-gdp-to-drop

TransFi. (2025, August 4). Cambodia's payment rails & how they work – Bakong, KHQR & the national push for financial inclusion. *Transfi*. https://www.transfi.com/blog/cambodias-payment-rails-how-they-work---bakong-khqr-the-national-push-for-financial-inclusion

UIDAI. (2020, August 5). *The Aadhaar Authentication for Good Governance (Social Welfare, Innovation, Knowledge) Rules, 2020* [Notification]. THE GAZETTE OF INDIA: EXTRAORDINARY. https://uidai.gov.in/images/Aadhaar_Authentication_for_Good_Governance_Rules_2020.pdf

UNHCR. (2024). *Ethiopia: UNHCR Operational Update, August 2024* [Press release]. https://data.unhcr.org/en/documents/details/111377

United Nations Conference on Trade and Development. (2021). *Digital economy report 2021: Cross-border data flows and development – For whom the data flow*. https://unctad.org/publication/digital-economy-report-2021

World Bank. (2020). *Nigeria Digital Identification for Development Project*.

https://documents1.worldbank.org/curated/en/250181582340455479/pdf/Nigeria-Digital-Identification-for-Development-Project.pdf

World Bank. (2021). *World development report 2021: Data for better lives.* https://doi.org/10.1596/978-1-4648-1600-0

World Bank Group. (2016). *Case study: Thailand PromptPay | December 2016 payment instruments.* https://fastpayments.worldbank.org/sites/default/files/2021-09/World_Bank_FPS_Thailand_PromptPay_Case_Study.pdf

World Bank Group. (2024). *Unlocking opportunities for refugees.* World Bank. https://www.worldbank.org/en/news/feature/2024/06/30/unlocking-opportunities-for-refugees

World Trade Organization. (2022, March 29). *Trade Digitalisation: TradeTrust*. World Trade Organization. https://www.wto.org/english/res_e/reser_e/pres_loh.pdf