Digital Public Infrastructure: Setting Standards with the Hourglass Model

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Abstract

Modern societies are increasingly relying on digital public infrastructure (DPI) to provide essential services such as identity verification, payments, and sharing of data. By setting standards with a principled yet pragmatic approach, governments can steer their DPI ecosystems toward greater inclusion, competition, and innovation, fulfilling the promise of digital infrastructure as a driver of sustainable development. Using case studies from countries that have successfully implemented DPI such as India (Aadhaar, UPI–Unified Payments Interface), Brazil (Pix), and Kenya (M-Pesa), this study sheds light on good practices in successful standard-setting and governance. These examples follow an hourglass model, with a small set of core standards at the "narrow waist" of the hourglass, supporting a wide variety of applications at the top of the hourglass, and interconnecting with a wide range of technologies at the base. The study assesses the conditions under which standards effectively become integral components of an optimal DPI, evaluates whether standards should be mandatory or voluntary, and explores their role within global technological ecosystems and international cooperation frameworks. It finds that components such as governance, policy, and design features that are adapted to the context are just as important to DPI as technology. It also highlights that strong public-private collaboration is essential to ensuring that DPI is adaptable and inclusive, and can be scaled. Lastly, the study advocates that effective standard-setting must be supported by robust institutional mechanisms to realize the full potential of DPI.

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Introduction

Digital public infrastructure (DPI) provides the digital foundations upon which a society operates and has transformed the way in which governments and societies deploy technology. It encompasses the shared and extensive digital systems and platforms such as digital identification systems, digital payment systems, and data exchange platforms that enable the large-scale delivery of essential services and that promote innovation. It is often complemented by sector-specific digital platforms in such areas as health care, education, and transportation.

The unifying idea behind "public infrastructure" is that these elements are public goods that provide open foundational layers (so-called "rails") upon which both public and private actors can "build" solutions, much like physical infrastructure (such as roads and electricity) does. As a result, DPI is now recognized as the "digital railbed" upon which whole economies run. When governments choose which technical standards become those rails, they effectively choose who can participate and innovate in the digital economy, and who can benefit from it. What are the core design features that DPI should adopt? Can they be used in any jurisdiction, in any cultural context, or for any level of development? Should technical standards and technologies be open source—available to anyone, freely for any purpose? If not, when should governments implement proprietary technologies? Is there a basic underlying norm (*Grundnorm*) of technological principles that can be implemented by countries globally?[1]

This study advocates the view that there are a few core standards—concerning identity, payments, and exchange of data—that unlock interoperability at scale, while still allowing countries to tailor applications and the infrastructure to their local needs. The study tests the following hypothesis:

> *Open, consensus-based core standards embedded in DPI accelerate inclusive growth, but implementation of these standards must account for the context. The one element that must be included is interoperability.*

The study also tests the following related assumptions:

1. The government is *required* to play a role in incubating technologies that have societal considerations because private industries lack the incentive to do so.
2. Technologies that are "generic" or "enabling," such as open-source or open-standard technologies, are more *rapidly adopted* in markets.
3. There is a "one-size-fits-all" DPI playbook of technical standards and principles.

The development promise of digital public infrastructure

Defining digital public infrastructure

The concept of DPI has been popularized only in the last decade, so definitions vary. But DPI can generally be described as a set of shared digital systems, governed by public-interest principles and legal frameworks, that provide important functions at scale (such as verification of identity, payments, and sharing of data) and that serve as the base for both public and private services (refer to box 1). Key attributes of DPI may include security, interoperability, open standards, and inclusivity (UNDP 2023). DPI is not only about digitizing government processes, the United Nations and World Bank have emphasized; it is also about creating common rails that others can leverage. DPI thus includes the "foundational digital building blocks designed for public benefit."[2] Specific sectoral platforms can be built around these core attributes, such as a health records system or an open education resources platform.

Box 1 The three components of digital public infrastructure

The D-P-I in "digital public infrastructure" encompasses the following three components.

Digital. At its core, DPI is designed for extensibility, modularity, and scalability, and is designed to, enable seamless interoperability and scalability as technology develops (be future proof). These features ensure that countries can build adaptable systems that can be widely scaled and that can grow with evolving technological and regulatory landscapes.

Public. DPI is inherently a public good, serving as a catalyst for both governance and market innovation. While it is built to facilitate efficiency, it also aims to fulfill critical public policy objectives such as enhancing competition, expanding access to sectors such as finance, education, and welfare, and fostering inclusion. By providing an open and scalable foundation, DPI prevents monopolistic control over essential digital infrastructure while unlocking new opportunities for businesses and startups, as well as governments.

Infrastructure. DPI function much like physical infrastructure. For example, just as roads do not dictate how vehicles should operate but rather provide a foundational layer that can be used by diverse transportation methods (such as sports cars, trucks, scooters and minivans), so does DPI provide a foundational layer upon which various platforms can be built. It provides common "rails"—such as digital identity, payments, and the exchange of data—that lower barriers to innovation and allow diverse actors to develop tailored solutions at scale. These common rails ensure that digital systems do not widen existing inequalities but actively mitigate them by enabling choice, competition, and interoperability.

Technical standards play a pivotal role in the success of DPI because they determine whether different systems can work together, whether users and providers are locked into proprietary ecosystems, and how easily new innovations can be absorbed into the infrastructure. A successful example of DPI in a developing country that has allowed diverse applications to flourish on a common foundation is India Stack—a set of open APIs (application programming interfaces) and specifications for verification of identity, payments, and sharing of data, among other functions (refer to the case study on India Stack for more information).

In theory, 'closed' approaches that do not implement open protocols have limited the degree of scale and innovation. Theory thus suggests that including the "right" set of standards in DPI can broaden inclusion and increase efficiency gains. On the other hand, the "wrong" set of standards can lead to fragmentation, vendor lock-in (reliance on a sole vendor), or stifled innovation. Following this reasoning, the Digital Economy Working Group of the Group of Twenty (G20) defines DPI as infrastructure built on "networked open technology standards" to enable interoperability and avoid vendor lock-in. The World Bank similarly notes that DPI should be interoperable and secure by design and governed by appropriate legal frameworks to ensure trust and inclusion (World Bank 2024a).

The World Bank's DPI Maturity Index identifies four tiers characterized by the level of interoperability and governance in place. In the lowest tier (nascent), digital systems exist but are siloed and minimally integrated. That is, there may be some government services available online, but there is no common identification or standards for data, nor are there any systemic policies in place. The next two tiers (emerging and scaling) are intermediaries. In the highest tier (mature), there is seamless interoperability across sectors and an adaptive governance mechanism that ensures the DPI is updated and aligned with global standards. This leads to the question that this study explores: If governments adopt open standards and enforce interoperability at the outset, does this arrangement guarantee the economy will rapidly develop?

Defining standards for DPI

Standards are the invisible infrastructure underpinning modern economies and governance. Standards are agreed upon norms, specifications, or criteria designed to be used consistently. There are several types of standards that relate to DPI:

- *Quality standards* provide requirements, specifications, guidelines, or characteristics that can be used consistently.[3]
- *Manufacturing standards* provide "how-to" instructions for designers, engineers, builders, operators, and decision makers to conduct disciplined activities within their domains.[4]
- *Technology standards* are norms or requirements that set uniform engineering or technical criteria. They are established by consensus and approved by a recognized body (Hart 2010).
- *Accounting standards* are a common set of principles, standards, and procedures that define the basis of financial accounting policies and practices.[5]

All types of standards serve to establish a "common language" by aligning definitions, measurements, and methods, thereby streamlining activities, reducing information asymmetries, and creating efficiencies across an economy. In order to streamline activities, standards require "buy-in" or acceptance. As a result, standards are typically created through some form of consensus—either evolving from private initiatives or from processes that involve the government to varying degrees (OECD 2020). In many cases, a recognized body or central body approve standards.

Standards can enable positive outcomes for development, including the following:

1. *Facilitating innovation and technology transfer.* Standards promote innovation, particularly in three domains: (1) research and development (R&D); (2) intellectual property rights; and (3) procurement processes. They also contribute to establishing focus, cohesion, best practices, and critical mass in the emerging stages of technologies and markets (Blind 2013). In countries like China, standards have directly contributed to economic growth and development, as they have reduced the time it has taken between technological innovation, diffusion, and application (Zhang et al. 2019).
2. *Facilitating integration with domestic and global markets.* Standards are the foundation of global trade, enabling goods, services, and data to flow more freely across borders. During the medieval European era when standard weights, measures, and coinage did not exist, merchants faced additional transaction costs when converting between local units, which hindered commerce (Tamura 2021). As common standards emerged, the fragmentation of markets declined, and trade flourished. The World Trade Organization's Technical Barriers to Trade (TBT) Agreement recognized that adopting international standards can enhance the competitiveness of exports for developing economies (WTO 1994).[6]
3. *Establishing quality assurance and trust.* Standards ensure a minimum level of quality and safety, thereby building trust—a prerequisite for the development of markets, particularly in sectors such as agriculture, manufacturing, or health care. For example, process standards for manufacturing (such as ISO 9001 for quality management) allow buyers to have confidence that suppliers follow consistent processes.

Public sector leadership in balancing innovation and regulation for DPI in developing countries: Lessons from India Stack, Pix payment (Brazil), and M-Pesa (Kenya)

Conversations around DPI typically attribute the infrastructure to the government, referring to it as "a country's DPI." However, most successful DPIs are entirely managed by private institutions. But governments do typically take the lead in the adoption of DPI, whether by convening stakeholders, mandating standards, or even directly building the infrastructure. Achieving the right balance between the role of the private and public sector poses a challenge in governance. On the one hand, too much involvement from the public sector may stifle innovation or discourage private investment. On the other hand, a laissez-faire approach with too little involvement may lead to a "race to the bottom" or to a few firms dominating the market.

The most advanced layer of DPI across emerging market and developing economies (EMDEs) is arguably the infrastructure for digital payments. All EMDE members of the G20 have at least one instant or real-time payment system that is either operational or being rolled out, and 93 countries around the world have an active, real-time retail payment system with a public-interest operator.[7] The protocol-like architecture of these payment systems that allow fast payment transfers has become a de facto standard. For example, UPI (India), Pix (Brazil), SPEI/CoDi (Sistema de Pagos Electronicos Interbancarios–Cobro Digital) (Mexico), IBPS (Internet Banking Payment System) (China), PayShap (South Africa), and FAST (Türkiye) are all real-time payment schemes that allow the instant transfer of funds. This rise in the number of real-time payment schemes is a huge leap from one decade ago when such infrastructure was limited to a few advanced economies. EMDEs have in many cases leapfrogged their more advanced peers in the volume of transactions.

This study's hypothesis suggests that a robust and interoperable DPI can increase the efficiency of governments by enabling them to use one system and to request data from citizens only once. Therefore, governments can use DPI to expand financial inclusion, increase access to services, and promote innovation in the private sector. However, implementing each layer of DPI also introduces new challenges that must be managed, such as technical complexity, demands on governance, and risks to privacy and cybersecurity. In addition, the implementation of these layers typically requires changes to legislation; hence government involvement is necessary. India, Brazil, and Kenya offer three successful examples of the implementation of DPI.

India Stack is a successful example of a fully layered digital infrastructure

India has successfully deployed a unified DPI at scale to bring its population into the digital age. Over the past 15 years, the country has built a comprehensive suite of digital public software platforms commonly referred to as India Stack, which includes three layers:

1. The *identity layer* is a reliable method to uniquely identify persons (and sometimes businesses or assets) online, such as a biometric ID or digital ID credential.
2. The *payments layer* is a fast, interoperable electronic payment system that is accessible to anyone, including for individual-to-individual transactions and individual-to-government transactions.
3. The *data exchange layer* is a mechanism for individuals and organizations to share data securely and with consent through data portability frameworks, digital lockers, and APIs for government data.

These layers are arranged in a so-called "stack." Table 1 outlines the various features of India Stack, along with the most recently available statistics on the use of each feature.

Table 1. Features of India Stack

Feature	Function	Most recently available statistics on use of the feature
Aadhaar (digital identity)	Universal biometric ID through fingerprints, iris recognition, and one-time passwords (OTP) that is used to authenticate the identity of the user across various sectors such as banking, telecom, and others.	• 1.419 billion Aadhaar numbers issued (as of May 2025).[a] • More than 2.84 billion authentication transactions during January 2025.[b] • 2.7 trillion authentication transactions during fiscal year 2024–25.[b]
Unified Payments Interface (UPI)	Open, real-time retail payment system that is enabled by an API (application programming interface) layer that allows any regulated payment app or bank to transfer and receive funds instantly using a virtual payment address, QR code, or phone number.	• 18.30 billion transactions in March 2025, and 17.89 billion transactions in April 2025, valued at about US$286 billion.[c] • 668 banks and payment apps used the interface in April 2025.[c] • Number of UPI QR codes increased 91.5 percent YoY to reach 657.9 million in fiscal year 2024–25.[d]
DigiLocker	Government-run cloud "document wallet" for citizens to store and share digitally signed documents such as licenses, diplomas, and identification cards.	• More than 270 million registered users and 6.7 billion documents issued and retrieved (May 2024).[e] • Supported the verification of more than 5 billion records.[e] • Feature is being adopted by other countries.
Account Aggregator (AA) Framework	Consent-based, open-finance standard that ensures a secure API avenue for individuals to share data on their bank accounts, insurance policies, or taxes with a third party.	• More than 140 million accounts linked in March 2025.[f] • 179.7 million requests for consent processed in total.[f] • 2.12 billion financial accounts have been AA-enabled.[f] • 112 FIPs (financial information providers) and 410 FIUs (financial information users) are currently participating.[f] • 17 licensed AAs (March 2025).[f]
ONDC (Open Network for Digital Commerce)	Open protocol set (including APIs for presentation of a catalogue, ordering goods and services, and managing logistics) that allows any app for selling and buying goods and services to interoperate, aiming to "unbundle" e-commerce.	• 16 million orders transacted during March 2025.[g] • More than 204 million transactions in total.[h] • Number of daily logistics orders surpassed 100,000 in March 2025.[h] • 760,000 sellers.[h]

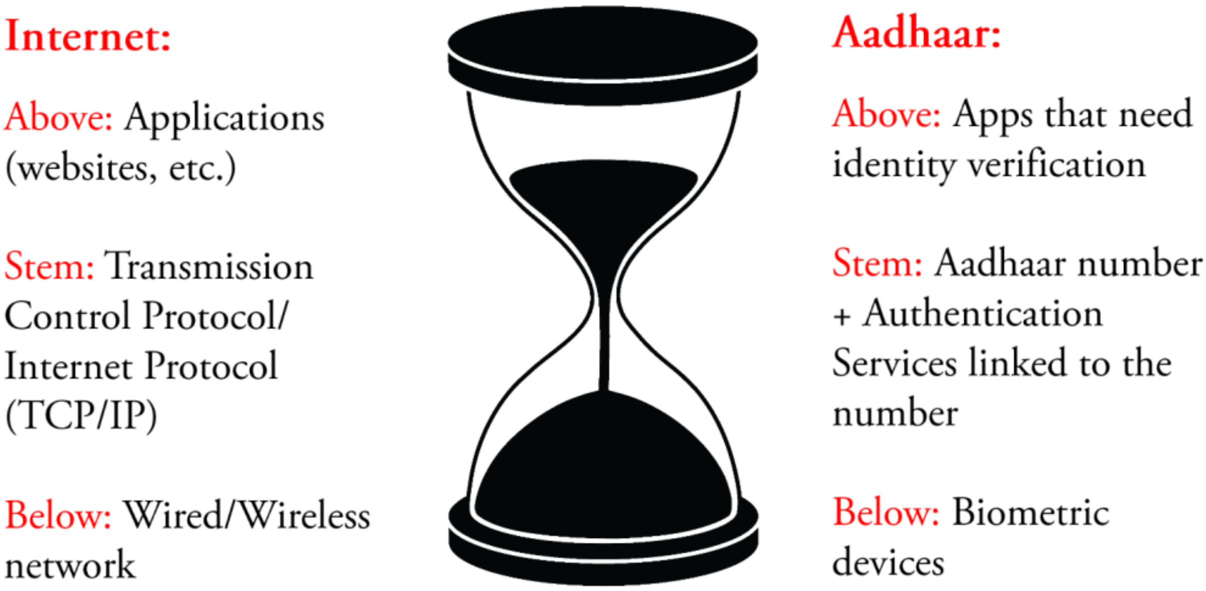
Source: Original contribution for *World Development Report 2025.*
Note: ID = identification; QR = quick-response, YoY = year over year.

a. https://uidai.gov.in/aadhaar_dashboard/.
b. India, UIDAI (2025).
c. https://www.npci.org.in/what-we-do/upi/upi-ecosystem-statistics.
d. India, RBI (2025), chapter 7.
e. https://www.digilocker.gov.in/web/dashboard.
f. https://sahamati.org.in/aa-dashboard/.
g. Goel (2025).
h. https://opendata.ondc.org/.

India Stack follows an hourglass model of standardization (refer to figure 1). A small set of core public standards forms the “narrow waist”. These standards guide the digital authentication of identification (through the Aadhaar system and DigiLocker); payment protocols (through the Unified Payments Interface [UPI]); and APIs for data consent (through the Account Aggregator [AA] framework and Open Network for Digital Commerce [ONDC]). This core supports a wide variety of applications at the top of the hourglass, and interconnects with a wide range of technologies at the base of the hourglass.

Keeping the number of core standards small (“thin”) and open has led to an increase in fintech apps, e-commerce solutions, digital health services, and other innovative services without requiring separate agreements for each integration. This model enabled a rapid scale up. For example, hundreds of banks and dozens of payment apps interoperated on the UPI within a few years, without the government needing to build every app itself. The government also prevented the creation of a monopoly because no single vendor owned the UPI standard or Aadhaar technology, which kept barriers to entry low. However, the governance challenge was how to maintain the neutrality and accountability of these core public standards.

Figure 1. Comparing the hourglass model of the internet to India Stack



Source: Singh 2018.

In the case of India, nonprofit organizations such as the National Payments Corporation of India (NPCI) and extensive consultations (including with private tech experts like the volunteer group iSPIRT) helped refine the standards, but it also led to concerns about private influence in what are seen as public systems. Thus, the experience of India demonstrates a negotiation of power, with the public sector providing legitimacy and the mandate, and the private sector contributing to innovation and technical capacity. The country’s experience also underscores the importance of institutional and policy support: the government set up dedicated institutions such as the Unique Identification Authority of India (UIDAI) for identify verification and National Payments Corporation of India (NPCI) for payments and enacted policies to increase uptake of these services, including waiving fees that merchants typically pay to payment service providers (merchant discount ratio [MDR] charges)[8] and adopting consent rules on data sharing under the Data Empowerment and Protection Architecture (DEPA).

But the changes took time. It took nearly a decade of litigation, executive orders, and legislative promulgation for users to gradually enroll in Aadhaar and trust the system. The initial uptake of UPI was slow before its explosive growth once the ecosystem was built. Notably, India primarily opted to increase uptake of the various features of DPI by providing incentives rather than mandating their use during the later rollout phase of DPI. For example, banks were encouraged (but not mandated) to join UPI, and citizens voluntarily linked to Aadhaar to reap its benefits related to banking. This approach of introducing voluntary adoption built trust among the intended users, and eventually UPI became so essential that regulators mandated that all banks offer all its customers access to UPI to prevent exclusion. This example shows how the public sector walked a fine line between avoiding overregulation to allow innovation to grow and regulating more heavily to ensure universal access or prevent abuse. But strategic patience, combined with a focus on open standards, reaped dividends. By 2023, India's DPI collectively handled billions of transactions and contributed significantly to economic output, with one estimate suggesting that DPI could boost India's GDP by 4 percent by 2030 (India, PIB 2025).

In addition to its potential contribution on the country's GDP, India's DPI has the potential to improve the country's development, including reducing poverty, improving financial inclusion for women (with many new bank accounts opened for female beneficiaries), and improving the transparency of governance. For example, introducing identity credentials (Aadhaar) has drastically lowered the cost of certain transactions, including but not limited to, complying with know-your-customer (KYC) requirements. This cost reduction led to an increase in the number of bank accounts through the Jan Dhan Yojana (public finance scheme) linked with Aadhaar eKYC, with 552 million accounts opened within the last 11 years.[9] DPI has improved the delivery of services through subsidies for digital transfers, it has saved billions of dollars by reducing fraud, and it has spurred private sector growth in India's fintech sector and digital startup ecosystem through the open rails provided by DPI (India, PIB 2025).

Challenges in the implementation of DPI remain. Civil society organizations and individuals have raised concerns about data privacy, which have led to the issuance of a landmark judgment by the Supreme Court of India and the passage of the Digital Personal Data Protection Act.[10] Another challenge is around ensuring equitable access to DPI services. About 35 percent of Indians are still unable to access the internet. Most basically, while DPI can enable access to services, complementary efforts in digital literacy and connectivity are needed for citizens to be able to use the services.

Brazil's Pix payment developed rapidly at scale

In Brazil, the government adopted a more assertive stance on standard setting for its instant payments system, Pix. In some ways, the implementation of Pix was Brazil's response to UPI. The system provides 24/7 instant transfers through a means of identification such as an e-mail address or phone number. However, Brazil pursued a different strategy than India. From the outset, it mandated all banks to join Pix, ensuring interoperability and rapid network effects from the start. Every bank and payment app was connected to the system, and it preempted the rise of incompatible private wallets. Pix achieved near-universal adoption among banks and tens of millions of users within one year of its launch—and within 18 months, more than 74 percent of the population was using the system, transforming Brazil's payment landscape.

However, banks did incur significant costs to comply with this mandate on a tight timeline, including having to channel significant resources in terms of money, time, and staff/support toward technical capacity building. Banks developed their internal systems to accommodate the new technology. Because banks were not charging any fees for using services on Pix, they created new products and services such as insurance, credit card products, and other alternatives that did incur fees. The Central

Bank also mitigated these costs by extensive consultations with industries and by providing technical specifications and support well in advance.

The experience of Brazil highlights the importance of the role of the public sector in not only setting standards but also in leveling the playing field against large tech platforms. For example, the Central Bank suspended Facebook's WhatsApp Pay in 2020 when the company sought to launch a proprietary payments service in Brazil, citing concerns over competition (Garcia 2020). Brazil pushed WhatsApp to use interoperable arrangements instead. This move was widely seen as a successful protection of the nascent Pix system by Brazil's regulator, ensuring that a global tech company did not bypass national standards, thereby preventing market distortion by a dominant player and funneling innovation into the common Pix ecosystem (Reuters 2020).

This study's hypothesis suggests that the approach adopted by Brazil in having the regulator set the standard may have reduced space for independent innovation in core infrastructure. However, in practice innovation thrived through the development of services that used the Pix platform, such as PicPay, PagBrasil, and Mozper, to name a few. Brazil now has one of the world's fastest growing and most inclusive payment ecosystems, with innovation in the fintech industry flourishing around the Pix standard. Even large industry players such as WhatsApp are integrating into the Pix system rather than creating their own. The use of Pix has expanded to cross-border payments through PagBrasil, which built its domestic payment stack using Pix in 2021 and rolled out international payments using Pix in 2023 (Fintech Times 2024). Overall, the experience of Brazil demonstrates that a public sector mandate on the use of these systems can rapidly achieve scale and positive outcomes such as universal access and interoperability. However, it requires having a strong regulatory capacity and the political will to confront entrenched interests from large actors.

Kenya's M-Pesa and PesaLink demonstrate that governments can choose to get involved later in the process

In Kenya, the private telecom company, Safaricom, launched the mobile money system M-Pesa in 2007. Unlike in Brazil and India, the system was launched in the absence of any public sector standard, and thus quickly became the de facto standard for digital payments in Kenya. M-Pesa soon dominated Kenya's mobile money market with a market share of 96.5 percent. As a result, the system became a DPI in its own right (Kaberia 2025). Unlike typical digital payment infrastructures that are government led, M-Pesa enabled cross-border transfers through private partnerships from the start. While increasing access, transaction costs to transfer money through M-Pesa are relatively high, at about 1 percent of the transfer amount.

By the mid-2010s, regulators encouraged interoperability between mobile money providers and between mobile money and bank accounts (and eventually ensured it). For example, Kenya's regulators supported the launch of PesaLink, an interoperable payments switch for bank-to-mobile transfers, and required mobile money operators to interoperate. The Kenya Bankers Association (KBA) developed PesaLink in 2016 through Integrated Payment Services Limited—a statutory body established in 2015 similar to India's NPCI that was created to advocate for interoperability and fair access to APIs (refer to table 2). The Central Bank of Kenya (CBK) has long advocated for structural reforms to improve oversight of the financial sector, including recommendations to separate M-Pesa from its parent company, Safaricom (Ekhator 2024). In January 2025, Safaricom proposed integrating M-Pesa with PesaLink to improve efficiency by leveraging PesaLink's existing infrastructure and the broad access of M-Pesa rather than building an entirely new system. From the perspective of the user, this meant that M-Pesa wallets would be able to interoperate with bank accounts as easily as bank-to-bank, reducing barriers to access and potentially reducing costs. If implemented, the integration would lead to the creation of a fully interoperable national payments grid, fulfilling the vision of the Central Bank without the need to create an entirely new system. While regulators will need to manage any emerging technical and operational risks, Kenya will have one of the most interoperable and inclusive payment ecosystems in the world if the integration is a success.

Table 2. M-Pesa compared to PesaLink

	M-Pesa	PesaLink
Year of launch	2007	2016
Structure of ownership	Private (Safaricom).	Consortium of banks (Kenya Bankers Association, KBA).
Primary function	Mobile money wallet and payments.	Interbank instant payment switch.
Number of users	About 34 million active users, comprising nearly 96 percent of the mobile money market.	Links 39 banks that account for nearly all bank accounts in Kenya. Its user base is all users who have a bank account (about 30 percent of adults).
Transaction limits	Limits have varied over time but have averaged a maximum limit of about K Sh 150,000 (US$1,160) per transaction, with an average daily limit of about K Sh300,000 (US$2,321).	Limit of K Sh999,999 (US$7,737) per transaction.
Avenues through which system can be used	Through mobile phone (SIM toolkit[a]/USSD[b]/app) and a vast network of agents for cash withdrawals and infusions.	Through banks (mobile/internet banking or USSD). There is no separate network of agents (uses bank branches/ATMs).
Degree of interoperability	Interoperable with banks that have integrated into the system. Fully operable with other mobile wallets (as of 2022).	Interoperable with all member banks, but limited direct link to mobile money payment systems (planned integration with M-Pesa by 2025.
Cost to users	Tiered fees based on amount of transaction, in addition to withdrawal fees. Fees are competitive for transactions of lower amounts but less so for transactions of higher amounts.	Fees are set by banks and are generally lower than non-bank money transfer services. Fees are often lower for transactions of higher amounts.
Regulatory oversight	Licensed by the Central Bank of Kenya (CBK) as a payment service provider. Subject to oversight by the Communications Authority (the telecom regulator) and CBK (the payments regulator).	Authorized by CBK as a payments system under the National Payment System Act and overseen by CBK, but governed through the rules of KBA.

Sources: Kenya, Communications Authority of Kenya 2024; GSMA 2024; Techpoint.africa 2025; https://www.safaricom.co.ke/m-pesa; https://pesalink.co.ke/; https://www.safaricom.co.ke/main-mpesa/m-pesa-for-you/tariffs-limits/consumer-tariffs-limits; https://www.centralbank.go.ke/.

Note: ATMs = automatic teller machines; SIM = Subscriber Identity Module.

a. The SIM toolkit is a standard feature on SIM cards that allows them to run small applications and interact with your phone and network provider.

b. USSD is a protocol that uses simple, short commands to interact with network services and display information on a screen.

As a private service, M-Pesa initially responded to a public need (access to finance) that traditional financial institutions were unable to meet. Its success raised the question: Should such a critical service be considered public infrastructure? Safaricom's motive to earn profit meant that the company could set its own fees and terms (within the regulatory limits). As a result, some have criticized M-Pesa for setting fees that are seen as high, particularly for lower-income users or for larger transactions. Reliance on a single private operator for most digital payments has systemic risks. For example, outages to M-Pesa have sometimes disrupted commerce nationwide, highlighting the economy's dependence on a single system. By contrast, PesaLink's bank-led model views digital payments as a public good, with some banks offering PesaLink transfers free of charge or at a minimal cost to gain customers. As a result, PesaLink is not seen as a profit-seeking initiative but rather as an enabler for the broader banking industry—and therefore, its value is in creating efficiency and potentially lowering costs for users. This "public service" approach is in contrast to M-Pesa's profit-seeking goal (from Safaricom), which generates substantial revenues through widespread use.

Table 3 summarizes the digital payment infrastructures of India, Brazil, and Kenya. Figure 2 highlights the volume of transactions of UPI (India), Pix (Brazil), and M-Pesa (Kenya) in 2024.

Table 3. Dimensions of digital public infrastructure in India, Brazil, and Kenya featured in the case studies

Dimension	India Stack (Aadhaar, UPI, DEPA)	Pix (Brazil)	M-Pesa and PesaLink (Kenya)
Structure of governance	• A mixed public-private approach. • Separate public agencies (UIDAI and NPCI) involved for each layer, with government setting the vision and the private sector (including the banking sector) implementing it. • Adoption for banks was voluntary at first, but later RBI mandated all banks to offer UPI. • Required coordination is complex with multiple institutions and regulators.	• Central Bank mandated all banks to participate, which ensured rapid nationwide rollout and universal access from the outset. • Public regulator enforced fair play by suspending WhatsApp Pay's proprietary rollout to protect Pix's open system. • Reliance on strong regulatory capacity and top-down coordination.	• Harnessed private market innovation, becoming the de facto national system. • Bank-led switch (through the introduction of PesaLink by KBA in 2016) to complement and interconnect with M-Pesa. • Intervention of public regulators will be required for interoperability.
Degree of inclusivity	• Aadhaar provided identification credentials to more than 1.3 billion people, enabling access to services and opening bank accounts. • UPI payments are available to any bank account holder (and recently to non-bank account holders), with simple mobile apps and even basic phones. • G2P payments (Jan Dhan Yojana) linked to these platforms resulted in the creation of 552 million new bank accounts, many for lower-income users.	• Pix reached tens of millions of users within one year of its launch, with 74 percent of Brazilians using it within the first 18 months. • Accessible 24/7 via phone and email, lowering barriers to access for users. • Transfers are free of charge or incur a minimal fee to encourage its use by citizens of lower-income levels.	• M-Pesa has 34 million users (comprising the large majority of Kenyan), including users who did not own bank accounts, and users from rural areas. This wide access vastly increased financial inclusion. • PesaLink serves users with bank accounts (comprising about 30 percent of the adult population). The primary benefit is the lower fees for transactions of larger amounts.
Degree of scalability	• India's DPI grew to scale over one decade.	• Nearly all banks adopted Pix and within one year,	• M-Pesa scaled gradually over a period of 15 years. The value of its

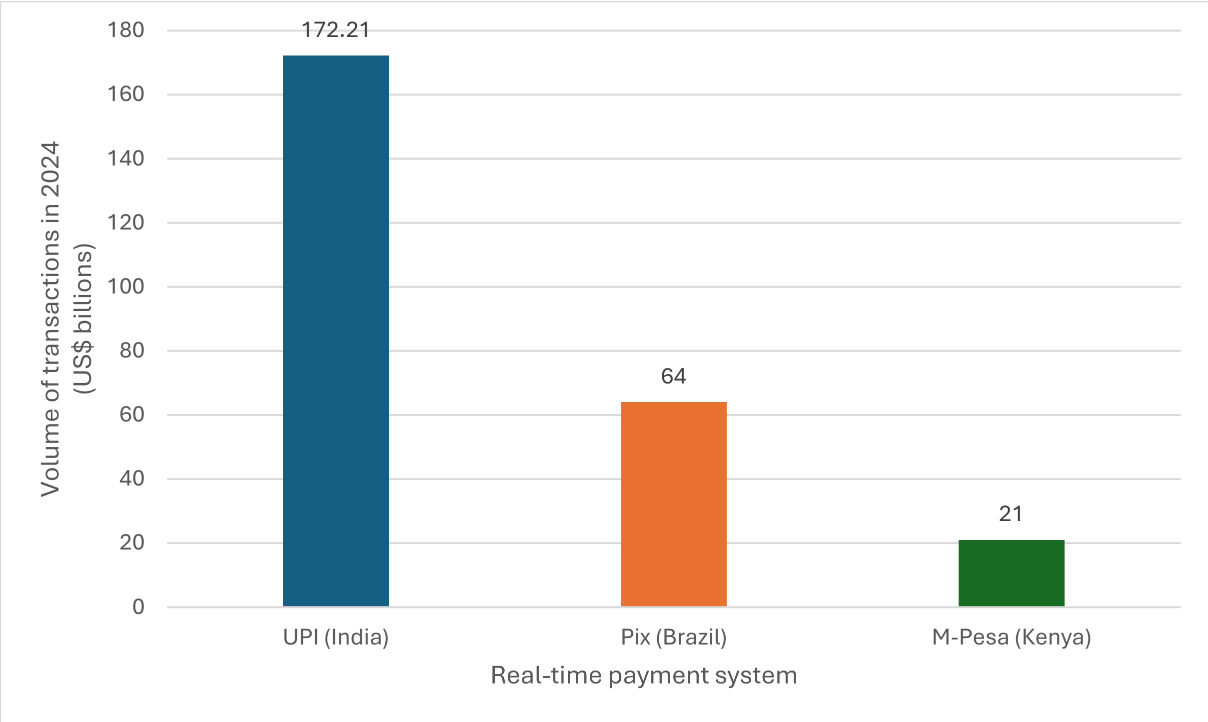
	• The number of users of Aadhaar increased steadily to eventually reach more than one billion. • UPI began in 2016 at a slower pace, but the number of transactions per month reached more than 9 billion by 2023 and 16 billion to 17 billion by 2025.	the system had handled massive volumes. • Using ISO 20022 has enabled Pix to scale up and expand its functions. For example, fintechs such as PagBrasil leveraged Pix to allow for cross-border payments. However, mandating the rapid implementation of Pix imposed some constraints on smaller banks. • Ongoing central coordination is needed to handle the expansion of Pix, as well as any technical issues that arise.	annual transactions has reached about half of the country's GDP. It was only suitable for small retail payments. • PesaLink was designed to be scalable for transfers of larger amounts between banks, up to K Sh1 million ($US7,741). • The reliance on one private platform has meant that outages have disrupted commerce nationally.
Degree of interoperability	• Interoperable "stack" across domains achieved through standardized QR codes, payment addresses, customer identification/KYC, and DEPA. • Open-source APIs allow sellers and banks to integrate.	• Full interoperability by design by mandating the adoption of a common platform, which eliminated incompatible silos. • Adopting ISO 20022 eased integration with global systems.	• M-Pesa was a closed loop until PesaLink linked banks with mobile money operators to enable full interoperability between banks and wallets. • The transition has required significant coordination between KBA, CBK, and Safaricom.
Degree of innovation and competition	• Open protocol supports dozens of third-party apps that offer different features but are interoperable with one another. • In practice, the market for UPI has been dominated by two players, requiring the regulator to intervene.	• The central bank oversees the core infrastructure, enabling innovation in services, in addition to focusing on the experience of users, credit offerings, and other services, around the Pix standard rather than the payment mechanism itself. • The central bank acts as an umpire in the case of WhatsApp Pay.	• M-Pesa APIs allowed entrepreneurs to create new services such as digital credit and savings apps that are tied to mobile money. • The addition of PesaLink to M-Pesa is expected to spur further competition, improved quality of services, and reduced fees for users.
Public–private collaboration	• India's DPI is a public-private coalition. The government funded and oversaw Aadhaar, with expertise on technology provided by the private sector.	• The central bank led the development of Pix in consultation with the financial industry such as banks and fintechs. • The government played a dual role as an enabler (providing the infrastructure and	• The current collaboration between M-Pesa and PesaLink is yielding results. If their integration succeeds, Kenya will have achieved a public-private interoperable system that leverages the

	• NPCI is a consortium of banks guided by the central bank. • DEPA was developed with input from both industries and civil society organizations.	technical support) and as an arbiter (ensuring that no private player dominated and undermined the public system).	strengths of both the telecom and banking sectors.

Sources: For India Stack: Carrière-Swallow, Haksar, and Patnam 2021; Chawala and Iyer 2025; NITI Aayog 2020; https://indiastack.org. For Pix: World Bank 2020; https://www.bcb.gov.br/en/financialstability/pix_en. For M-Pesa and PesaLink: Dabafinance 2025; Kariuki 2025; Techpoint.africa 2025.

Note: API = application programming interface; CBK = Central Bank of Kenya; DEPA = Data Empowerment and Protection Architecture; DPI = digital public infrastructure; G2P = government-to-person; KBA = Kenya Bankers Association; KYC = know your customer; ISO = International Organization for Standardization; NPCI = National Payments Corporation of India; RBI = Reserve Bank of India; UIDAI = Unique Identification Authority of India; UPI = unified payments interface.

Figure 2. Transaction volumes of UPI (India), Pix (Brazil), and M-Pesa (Kenya) in 2024

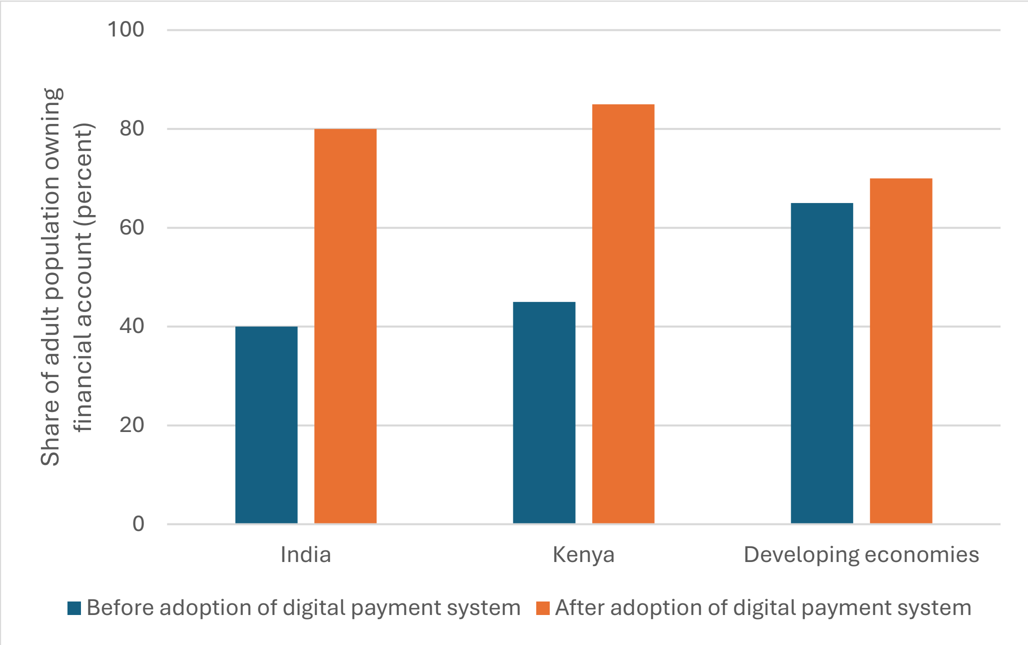


Sources: For India: India, NPCI 2024; for Brazil: https://www.bcb.gov.br/en/financialstability/pixstatistics; for Kenya: Safaricom 2024.

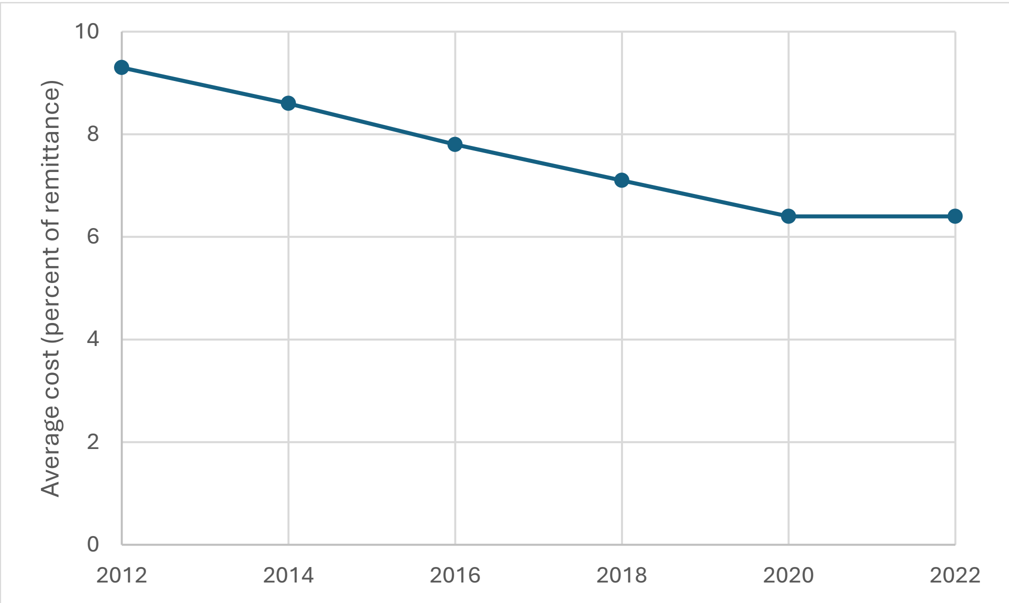
Figure 3 shows the positive impact on the economy of countries that adopted digital payment systems. The share of the adult population owning a financial account after the implementation of digital payment systems increased in India, Kenya, and developing countries more broadly (refer to panel a). The implementation of digital payment systems also reduced the average cost of sending remittances globally over time, from 9.3 percent of the remittance amount in 2012 to 6.4 percent in 2022 (refer to panel b). And GDP grew by 5 percent on average in countries with higher rates of adoption of digital payment systems, compared with 2 percent in countries that had lower rates of adoption (refer to panel c).

Figure 3. The economic impact of adopting digital payment systems

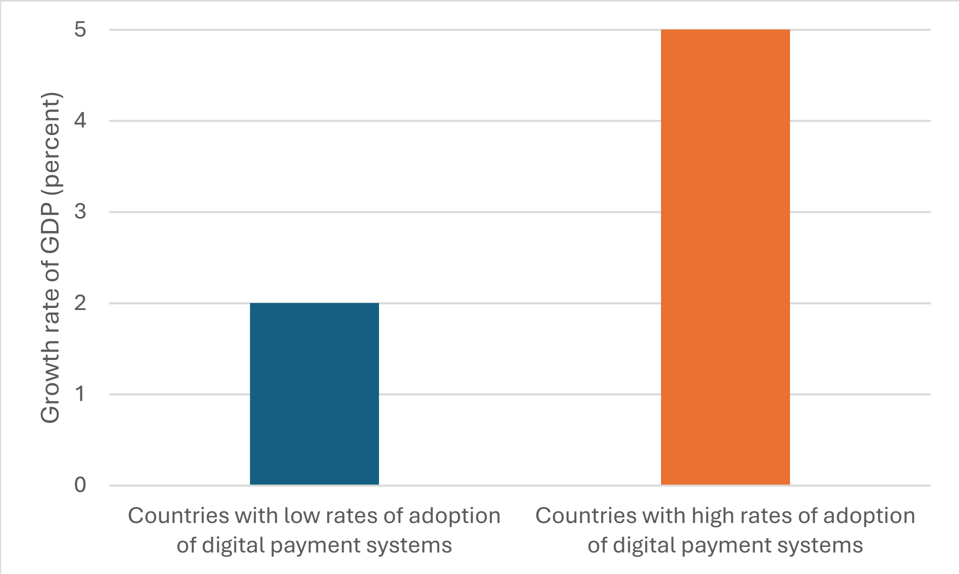
a. Share of adult population owning a financial account before and after the adoption of digital payment systems



b. Average cost of sending a US$200 remittance, 2012–22



c. Growth rate of GDP in countries with low rates of adoption of digital payment systems and high rates of adoption



Sources: For panel a: Demirgüç-Kunt et al. 2022; for panel b: World Bank 2023; for panel c: Manyika et al. 2016.

Challenges to adopting and implementing DPI

As demonstrated in the case studies, modern societies are increasingly relying on DPI to provide essential services such as identity verification, payments, and sharing of data.

Notably, the exchange of data at scale is critical to successful implementation. The impact around the world, and on EMDEs in particular, have been rapid and far-ranging. From broad-based identification systems that handle billions of authentications to payment networks routing high-frequency transactions, the success of DPI in many ways determines the direction of the global economy. For example, enabling the exchange of data at scale supports the inclusive provision of services—reliably identifying who receives benefits (as well as which benefits) and enabling digital collaboration across borders, particularly in fast-growing sectors such as e-commerce, digital finance, and remote health that are critical sectors in EMDEs. Because EMDEs have larger informal sectors and lower levels of financial inclusion than advanced economies, digital reforms in these economies yield significant results. For example, between 2008 and 2012, GDP increased by 6 percent on average in EMDEs when they adopted digital identification, compared with 3 percent in advanced economies (Zandi, Singh, and Irving 2013). By increasing access to the formal banking system and reducing the use of cash, EMDEs can increase tax revenues and accelerate economic growth. The impact of digital payment systems, mobile money, and digital identity and productivity on GDP on EMDEs includes the following.

1. *Digital payment systems.* A study of 101 countries between 2014 and 2019 found that for each percentage point increase in the use of digital payment, the GDP per capita growth rate increased by 0.10 percentage points over two years, after controlling for the diffusion of information technology (IT) and informality (Aguilar et al. 2024). In contrast, a study of 56 economies between 2008 and 2012 reported higher rates in the use of credit cards increased the average annual GDP growth rate by 0.17 percentage points and increased cumulative output by US$983 billion (in 2008 US dollars), with GDP in EMDEs increased by 0.8 percent compared with 0.3 percent in advanced economies (Zandi, Singh, and Irving 2013). In China, the share of transactions paid for by credit cards increased from 31 percent to 56 percent between 2008 and 2012, which corresponds to an estimated increase of 1.7 percent of GDP.

However, China's expansion has been led by non-card digital payments e.g., Alipay/WeChat Pay. (Zandi and Singh 2021)

2. *Mobile money.* An increase in the adoption of mobile money by 10 percentage points increased GDP by 0.6 to 1 percent between 2013 and 2023, analysis on mobile money markets conducted by Groupe Spéciale Mobile Association (GSMA) demonstrates. By the end of 2023, the adoption of mobile money had increased a country's GDP by 1.7 percent on average. In West Africa, GDP increased by 4.1 percent more in countries that adopted mobile money than in countries that did not. In East Africa, that difference was even greater: 5.9 percent. This adoption of mobile money translated into an additional US$600 billion to a country's GDP (GSMA 2025).[11]
3. *Digital identity and productivity.* A study conducted by the McKinsey Global Institute of digital identification across seven countries found that having a comprehensive ecosystem has the potential to increase a country's GDP by 3 percent to 13 percent by 2030; the average increase is projected to be 6 percent increase in emerging economies and 3 percent in advanced economies (White et al. 2019). A 2016 study found increases particularly have been as a result of gains in productivity from implementing know-your-customer (KYC) standards, improved provision of public services, and the automation of transactions (Manyika et al. 2016). In Estonia, the government has estimated that the implementation of its e-ID program, which enables legally binding digital signatures, led to annual savings in the national budget equivalent to about 2 percent of the country's GDP, largely as a result of a reduction in paperwork and faster transactions (IPI 2016).

While these high volumes of digital transactions have had a positive impact on various economies around the world, they have also raised challenges.

Among these are concerns about personal rights to data privacy, regulatory compliance, and cross-border governance (OECD 2024). These concerns imply that robust, principle-based governance and public-private collaboration are essential when developing a new technology or protocol (World Bank Group and Endorsing Organizations 2021). The aim of most DPI programs is to increase financial inclusion and boost economic development. As a result, the type and extent of its outcomes should determine the degree of success of a DPI, rather than its ability to meet any intrinsic technical specification (Ardic Alper et al. 2023). For example, in India, the e-KYC initiative enabled by Aadhaar, the Jan-Dhan basic accounts, and the UPI together increased the share of adults who own a financial account from 53 percent in 2014 to 78 percent in 2021. Yet only 17 percent of adults in of India used their financial accounts to save and only 12 percent borrowed from a formal institution in 2021—demonstrating that gains in access to financial services have not yet translated into broad uptake of credit or savings products (Demirgüç-Kunt et al. 2022; EY 2024; FinDev Gateway 2022). Global Findex data from 2021 show that about 45 percent of adults in India reported borrowing money in the past year, but fewer than one-third of those borrowers went through formal channels such as a bank or microfinance institution (Demirgüç-Kunt et al. 2022). In other words, only 10 percent to 15 percent of adults borrowed from a formal financial institution, with most borrowers relying on family, friends, and other informal lenders. Similarly, only 2 percent of Indians own a credit card, compared with 8 percent in South Africa and 29 percent in Brazil.

These statistics on the low use of formal financial services highlight a stark contrast. India has achieved near universal ownership of bank accounts, yet use of the formal credit system is very low relative to other large emerging economies, largely due to stringent regulations. Until recently, regulation on digital lending was quite stringent and onerous, peer-to-peer lending was restricted, and banks did not rely on nontraditional data for credit scoring, such as livestock and farming assets. Therefore, while DPI removed the barriers to verifying identification and enabled digital payments, the high risk in the credit market still remains. Traditional credit bureaus in India such as TransUnion CIBIL still lack sufficient and reliable data on most customers who have recently opened financial accounts because they have not yet applied for loans nor credit cards. The Account Aggregator (AA) framework (run by the nonprofit organization, Sahamati) allows individuals to share their financial data with lenders, but it covers only 8 percent of adults in India. However, the coverage is projected to increase to 20 percent by the end of 2025, largely due to the regulatory support the Reserve Bank of India is providing to Sahamati (Sahamati 2024).

These examples highlight that components like governance, policy, and design features that are adapted to the context are just as important to DPI as technology. The examples also highlight that public-private collaboration is essential in the setting of standards for DPI. Brazil, India, and Kenya all formed working groups with the relevant industries to collect feedback. They also launched the DPI through phased rollouts. In addition, these countries adopted a phased approach to regulation. That is, they adopted few regulations at the outset to allow room for innovation, but adopted more regulations to tighten standards as the ecosystem matured. While the public sector played different roles in each country, it played the role of architect and convener in all three cases, establishing the technical standards and legal framework for their respective DPIs and ensuring access to all, while leveraging the dynamism of the private sector to build and populate the infrastructure.

Three-quarter of countries with digital identification systems, including most EMDEs, have adopted specific laws or regulations that define the status and use of the system.[12] For example, countries like Colombia, India, Indonesia, and Mexico have adopted identification acts or updated their civil registry legislation to recognize digital identification as a legal means of identity verification. However, about one-quarter of countries around the world lack dedicated legislation on digital identification, and 11 percent of countries have digital identification in place but lack accompanying legislation on data protection, which poses a potential risk to privacy and trust. India adopted the Digital Personal Data Protection Act only recently (in 2023), nearly 15 years after the launch of Aadhaar. Brazil, on the other hand, adopted its General Data Protection Law at the same time that it scaled its digital identification system.

The institutional management structure of digital identification systems varies widely across EMDEs. In about one-third of countries globally, the digital identification system is housed within a dedicated civil identification authority or population registry; in about 28 percent of countries, a digital government agency oversees the system; and in about 22 percent of countries, security agencies or internal affairs agencies oversee the system. For example, in India, UIDAI is an independent agency focused on digital identification. In Brazil, a national civil identification service under a citizen services department manages the digital identification system. In Mexico, the National Population Registry (RENAPO) is under the Ministry of the Interior. And in Türkiye, the Presidential Digital Transformation Office oversees the digital identification system through the e-Devlet portal. The choice of agency overseeing digital identification affects trust in the system and interoperability. For example, a digital agency that is not under the mandate of an agency focused on security may emphasize the integration of services, whereas one that is housed under an agency focused on security may prioritize control. Regardless of the model, mechanisms for accountability are often still evolving. Few EMDEs have clear judicial oversight or external audits for their identification systems.

The openness of systems also raises challenges. There is also common perception that interoperability and openness are nonnegotiable principles for DPI, and that the absence of these two principles leads to e-government systems that are isolated or to vendors providing digital services that are siloed and thus cannot realize equitable network effects. In practice, DPI has a positive impact on development when it is accessed by a critical mass of users. In India, Aadhaar's open authentication APIs enabled hundreds of private and public apps (from mobile wallets to vaccination certificates) to use the digital identification as an additional layer of verification. Brazil's new identification card links to a unified digital login (through www.gov.br) that citizens can use to access more than 4,000 services. The Mi Argentina digital identification app similarly allows users to authenticate their identification for a range of services.

By contrast, some countries initially limited the use of digital identification systems. For example, Indonesia and Mexico initially allowed the use of digital identification only for government transactions and for accessing online banking services but are now enabling the integration of private sector transactions. Most countries recognize that a broad adoption of DPI requires that it be made available across multiple sectors. But only 57 countries have digital identification systems operational in at least two sectors (a criteria for a true DPI-grade identification), according to the DPI Map. Many EMDE members of the G20 have exceeded this threshold, enabling the use of digital/electronic identification in multiple sectors, including in finance, social protection, health, and education.

The challenges of open standards and open-source technologies

The "openness" of standards can take different forms, which do not necessarily lead to optimal outcomes

Open standards are those that are generally accessible to all potential adopters without restrictions of use, while closed (proprietary) standards are typically under the control of a single firm or consortium, which may impose licensing fees or constraints on their use. Governments with limited leverage to negotiate or limited R&D capacity often prefer open standards to avoid vendor lock-in and high licensing costs. Open standards can lower barriers to entry for local firms, spur capacity-building at the local level, and encourage innovation by ensuring that core technologies are accessible. However, there are also benefits to proprietary standards developed by large firms that offer cutting-edge features or establish ecosystems that have value in the short term. For example, the creation of iOs and Windows has brought about widespread benefits, fueled by the initial adoption through promotional pricing or licensing "bundles," which sped up the uptake of networks in the short term (Farrell and Saloner 1986).

Scholars have noted that the term "open standard" can be politicized. For example, a standard may meet the criteria for openness designated by a particular standards development organization, yet it may fall short of what public interest advocates consider to be open. In addition, many open standards require adhering to licensing agreements or are governed by particular organizations such as the Internet Engineering Task Force (IETF). Even proprietary standards sometimes allow partial access through alliance agreements or through licensing fees. A seemingly open standard can vary in how it is developed, published, and implemented, which can affect outcomes. "Openness" is a fluid concept. It has three dimensions.

1. *Openness in the process of development.* This dimension refers to *who participates* in creating the standard. A completely open process of development is one that is transparent and inclusive. The standard is managed and developed independently of any single vendor in a process in which competitors and third parties participate equally. In practice, an open process of development can take many forms, ranging from fully public forums to closed industry consortiums.
2. *Openness in access (publication and transparency).* Openness in access means *the specification is publicly available and can therefore be implemented by anyone*. With an open standard, the technical specifications are made publicly available, without any constraints to accessing them.
3. *Openness in implementation (fees and licensing for intellectual property rights).* One of the most contentious aspects of open standards is licensing—specifically, whether those that

intend to implement the standard must pay royalties or face restrictions on patenting. Some standards development organizations label a standard "open" if it is available under fair, reasonable, and non-discriminatory (FRAND) terms, which often still involve patent licensing fees. For example, many telecom standards such as 3G and 4G are made available under FRAND terms, but adopters must pay licensing fees. By contrast, open information technology (IT) policies such as the European Union's European Interoperability Framework (EIF) and the United Kingdom's Open Standards Principles require that standards be made publicly available without adopters needing to pay royalty fees in order to maximize accessibility. In practice, there is a spectrum to the degree of openness in implementation. On one end, standards such as HTML are free of charge to adopt and implement, and access to them is unencumbered. On the other end, some standards are controlled by a single entity's patents and are only available under licenses.

This spectrum in the degree of openness means that no standard is entirely open or closed (David 1987). Large standards development organizations such as ISO (International Organization for Standardization), the IEC (International Electrotechnical Commission), and ITU (International Telecommunication Union) often adopt a less stringent definition of openness that permits limited restrictions but ensures that the process to develop the standards is transparent. For example, ISO categorizes standards that require patent licensing under FRAND terms as open if the process of development was transparent and inclusive and the terms are non-discriminatory. However, governments and advocates of open technology standards often advocate for a stricter definition that requires the process to develop standards to be fully transparent, to ensure that access to the standards is free of charge, and that there are no barriers stemming from intellectual property rights. In their view, the approach taken by standards development organizations to label a standard as open even if a royalty must be paid for each use could exclude nonprofit organizations, startups, or open-source projects. In addition, governments often prioritize outcomes. They seek standards that enable interoperability at a low cost and with minimal dependence on external patent-holders or vendors.

Not only is there a spectrum in the degree of openness, but a standard may be considered open in one sense yet closed in another. For example, the GSM mobile telephony standard is openly published and globally adopted, but some portions of it are patented under FRAND—that is, they are accessible, but adopters must pay royalty fees. Such nuances in the openness of standards matter for DPI projects. Governments must not only ask the question "Is this an open standard?" but also "In what ways and to what extent is it open?" and "Does a particular level of openness suffice for public needs?"

All standards, including open standards, have costs: lessons from adopting the ISO 20022 standard

The experience of South Africa is a successful example of a government that determined the use of standards in a manner that avoided vendor lock-in and ensured broad accessibility. In 2007–08 South Africa advocated for the adoption of the OpenDocument for government.[13] This standard is in contrast with the ISO-approved Office Open XML (OOXML) file format, which is categorized as an "open" standard but which many view as heavily controlled by one vendor (Microsoft) and encumbered by complexity and patent concerns (Rens 2011).

In contrast to the approach taken by the government of South Africa, some standards development organizations have prioritized setting standards based on consensus from industries, even in cases where proprietary influence existed. The Pix payment system in Brazil meets the substantive criteria of an open payment standard: all documentation is publicly available; there are no barriers to intellectual property; access is available to everyone; and interoperability is mandatory. However, it can be classified as an "open, regulator-mandated standard" because the system is centrally governed to protect safety and efficiency.

In the area of domestic payment transfer systems, many countries have adopted various standards over the years, such as ISO 8583 (as in Chile) (World Bank 2021), ISO 15022, American National Standards Institute (ANSI) X12, and the UN's Electronic Data Interchange for Administration, Commerce and Transport (EDIFACT). The most dominant standard for card-based financial transactions globally remains ISO 8583, an international standard for electronic financial transaction messages. Published in 1987, it is now applicable to 95 percent of card-based payments (World Bank 2022b). The 1987 version continues to be the most widely implemented, despite subsequent updates in 1993 and 2003.[14]

In 2013, a successor standard, ISO 20022 was published as a global standard for financial messaging, providing standard messaging models for domains such as payments, securities, trade services, card services, and foreign exchange (FX).[15] It is the standard that underpins Brazil's Pix payment system.

An increasing number of payment systems are adopting ISO 20022. An average of 1.4 million payments are transacted daily under this standard, spanning 150 "sending" countries and 220 "receiving" countries (SWIFT 2005). For example, in India, NPCI originally used the ISO 8583 messaging specifications on its immediate payment service system (IMPS), but phased it out once all national payment systems began the migration to ISO 20022, with the uniform goal of enabling the transfer and receipt of remittances across borders. However, as of September 2023, only 15 percent of outgoing messages from India followed the ISO 20022 standard.

The migration from ISO 8583 to ISO 20022 provides remarkable insights into how standards are adopted, mandated, and sometimes fail to achieve global traction. A report conducted by the European Card Stakeholder Group (ECSG) finds that the most optimistic payback periods range from 11 years for updating ISO 8583 systems to 18 years for adopting ISO 20022 systems (ECSG 2018).[16] These lengthy periods make transitioning to a new technology undesirable. The cost to upgrade the payment systems also varies and can be a significant impediment for small and medium markets. Payment service providers face significantly higher costs to upgrade than users of the services. However, it is the lack of clear efficiency gains for businesses that explains the slow rates of adoption of ISO 20022.[17] A report conducted on the implementation of the Single Euro Payments Area (SEPA) found that payment service providers that migrated to ISO 20022 experienced mixed results in efficiency, with 28 percent of payment service providers reporting slower transaction times and 53 percent noting increased transaction costs (Europe Economics 2016). Financial institutions also currently incur the costs of "conversion" between different formats in data. The SWIFT network repeatedly postponed the deadline for their member institutions to implement ISO 20022 (first, from 2021 to 2022, then from 2022 to the first quarter of2023, and now to November 2025) due to challenges faced by members in preparing for the implementation (SWIFT 2025). Similarly, the U.S. Federal Reserve postponed the migration of the Fedwire Funds Service to ISO 20022 from March to July 2025, indicating persistent barriers to implementation across the financial industry.

In addition to the high cost and lack of efficiency gains from migrating from ISO 8583 to ISO 20022, other challenges include the diversity and number of market participants, the complexity of the market, and the absence of a compelling business justification for a comprehensive transformation to ISO 20022 across all sectors of the financial industry. A market-driven approach to migrating to ISO 20022 that is based on business considerations is preferable to mandating the migration.

Lessons learned from the migration to ISO 20022 including having the option to choose when to use ISO 20022 or ISO 8583, support for lower-income participants, and alignment of incentives for adoption. While practical decisions like ensuring that ISO 20022 is compatible with ISO 8583 and a phased rollout may have addressed some of the challenges, the main lessons learned are based on revising the principles of the standard. A core standard that entails fewer requirements and is easier to implement could result in a faster rate of adoption and then continue to evolve. Standards that are based on too many requirements can result in lower rates of adoption. Future efforts to create standards should incorporate capacity-building, such as the provision of free or low-cost implementation toolkits, testing sandboxes such as the Financial Conduct Authority (FCA) sandboxes for innovation,[18] and trainings.

Open standards can still lead to closed outcomes

What drives the adoption of standards in general, and with respect to the adoption of DPI within a country? More importantly, can DPI drive the adoption of standards globally? Despite spanning a range of domains, most standards emerge through a mix of consensus-building and a "top-down" approach. Many technical standards are set by voluntary standards development organizations that convene experts, industry practitioners, and sometimes governments, such as ISO and the World Wide Web Consortium (W3C). Governments also play a role, often through national regulators, legislations, and rules. They may mandate standards through the adoption of regulation (particularly to ensure public safety or preserve public interest) or incorporate international standards into national legislation. Therefore, the process of standard setting often occurs through four avenues: (1) development of standards by industries (such as REST APIs enforced by Android); (2) competition among sponsored (proprietary) standards (such as XML by Microsoft); (3) development of voluntary standards in formal standards development organizations; and (4) adoption of mandatory standards through government regulation.

The common thread among these four avenues is that broad buy-in is key to the success and legitimacy of a standard, regardless of whether it was created because of market necessity or mandated by a government. For example, the Ethereum ecosystem—a network of projects, applications, and users built around the Ethereum blockchain—adopts a community-driven approach to the development of standards. Standards are created through Ethereum Improvement Proposals (EIPs) where developers and users worldwide propose and refine technical specifications. A subset of these standards—the Ethereum Request for Comments (ERCs)—defines interfaces for smart contracts, including the ubiquitous ERC-20 token standard that established a common framework for fungible digital assets and has become the de facto norm for fungible tokens, facilitating the creation of thousands of new digital assets. As of 2024, more than 450,000 ERC-20 token contracts have been deployed on the Ethereum main net (Ethereum's production server), with a total market capitalization value exceeding $US200 billion.[19] While many other layer one chains have emerged since then,[20] including Solana, Polkadot, and NEAR, 80 percent of the top 10 chains are compatible with EVM (Ethereum Virtual Machine). Chains that are not compatible with EVM such as Terra and Solana are developing EVM-compatible solutions or can already operate within Ethereum's account system. This example of a purely decentralized Web3 ecosystem demonstrates that the most successful standards set by industries are those that are adopted by the majority of consumers. Consumer adoption can lead to convergence from disparate local standards to a more international standard being adopted to the local context.

Market forces can often come into play in the case of open standards if market outcomes are closed or concentrated. While open standards can enable competition, they do not guarantee a competitive market. For example, in India, UPI is an open interoperable payment system that dozens of banks and apps have adopted. Yet PhonePe and Google Pay have accounted for about 80 percent of UPI transactions, requiring the regulator to step in (Gupta 2025). This domination of the market is not indicative of a failed standard, as the APIs and network did remain open to all. However, it demonstrates that network effects and advantages of "first-movers" can concentrate the use of the system among a few market players.

Similarly, Android is an "open-source" mobile operating system, but Google's dominance in the ecosystem has led to the creation of certain web standards (like those for progressive web apps or next-gen image formats) that it subsequently adopts in its browser and services, effectively guiding the ecosystem in a direction favorable to its products. In DPI, large firms might support an open standard for the exchange of data in finance, hoping to leverage their superior data analytical capabilities amidst an inundation of interoperable data. Smaller local firms may lack a similar capacity. Therefore, even when a standard is open, the ability of firms to capitalize on it is not equal.

This lack of a level playing field for all firms implies that complementary policies such as legislation on data governance and competition is needed for all firms to reap the benefits of open standards. Late mover jurisdictions could thus prevent monopolistic or anticompetitive outcomes by "baking in" open standards, coupled with legislative scaffolding. The example of GPay and PhonePe underscores that open standards must be coupled with proactive governance. If governments establish the rules of the game early in the process by ensuring that all users connect through open interfaces, this can prevent the entrenchment of an incumbent, even in cases when the incumbent is a private actor with significant advantages.

Another risk is the "thin market" or sustainability problem for open technologies. Open standards often maximize downstream innovation. That is, when a standard is open and free to implement, many different providers can build on it, leading to competition in its implementation and in value added services.

But the challenges of open-source technologies and open standards are to continually maintain them and to avoid "free-rider" problems. There have been instances where some low- and middle-income countries have adopted an open-source DPI component that eventually failed because of a lack of local capacity to maintain it. On the other hand, stakeholders that have an abundance of resources such as global tech firms or government agencies in major developed countries are well positioned to maintain open standards, either through participation in standards development organizations to continually update the standard or through contributions to open-source projects.

Unlike a proprietary vendor product where a contract ensures support of the standard (albeit at a cost), an open solution might suffer from problems of collective action where users may assume that another stakeholder (typically the international community or volunteer developers) will handle updates and security patches. This mindset can lead to the standard eventually becoming obsolete. These risks should not deter the adoption of open standards, but rather they highlight the importance of investing in local capacity and governance alongside the adoption of the standard to ensure that it remains viable.

Mandating openness in public infrastructure should be a pragmatic choice

On the one hand, there is a compelling case for mandating openness, particularly for core layers of DPI. Because public infrastructure is seen as a public good, the argument follows that it should not be subject to constraints on private intellectual property or technologies that dominate the market. By insisting on royalty-free and open standards in procurement, governments can avoid paying fees to foreign patent holders, reduce the total cost to the government, and stimulate the domestic tech ecosystem because local firms are more likely to adopt and build on technologies that they can use freely.

Several governments and international bodies have adopted "open standards policies." For example, the European Union and countries like Brazil, India, and South Africa have adopted policies favoring the use of open standards in government ICT (information and communication technology) systems. In India, the Policy on Open Standards for e-Governance requires that preferred standards have no royalties and that their use be unrestricted, a response to concerns that reliance on patented technologies could compromise national digital sovereignty. The G20 has also highlighted the importance of "networked open technology standards" in DPI to ensure interoperability and avoid vendor lock-in (G20 2023). These positions reflect the view that core government systems such as identification, payments, data exchange platforms should not require the use of proprietary software or the payment of licensing fees as a condition of interoperability. Mandating open standards also encourages vendors to offer solutions that conform to these standards, or risk being ineligible to bid for government projects.

On the other hand, a stringent mandate to use only fully open standards can be challenging, particularly if the mandate excludes the use of any standard that involves patents under FRAND terms. First, in certain technology domains, all available standards may involve some patented technology. Thus, a mandate to not use any patented technology could lead to the adoption of a less mature technology that is less supported. For example, in mobile telecommunications or encryption, globally adopted standards are often developed by industry consortiums with patent pools. It would be impractical and costly for a government to develop an entirely new standard simply to avoid patents. Rather, it should use the de facto industry standard (even if it is not completely open) to ensure compatibility with global systems, while still negotiating the terms of use or relying on vendors who are licensed.

Second, taking a rigid stance on open standards may limit innovation or quality if the proprietary option is significantly more advanced because a proprietary technology may offer features or a level of performance that is not yet matched by any open alternative.

Governments thus face a trade-off between following a principle of openness and immediate functionality. The decision to mandate open standards may depend on whether a suitable open solution exists and on the strategic importance of autonomy in that domain. For example, many countries choose to adopt open-source platforms such as modular open-source identity platform (MOSIP) for digital identification or OpenCBS (open core banking system) for core banking. In other cases they may adopt a proprietary solution in another domain, with the intention of migrating to open standards once the field matures.

The emerging consensus in practice is for governments to adopt a hybrid, principles-based approach: that is, use open standards wherever possible, particularly with interfaces, but consider adopting proprietary technology if it serves the public interest, with the understanding that no proprietary element should undermine the overall openness of the system. In other words, governments should ensure that critical interfaces and data formats remain under public control and that they are based on open specifications, even if some internal modules or ancillary tools are provided by private vendors.

Many governments have adopted this pragmatic approach. For example, a country could mandate that all data exchanged in its digital health DPI use an open format (and therefore ensure interoperability among vendor systems), yet the software used by a particular hospital may be a commercial product. The most important component is that the interoperability layer is open. If the government (or a public consortium) controls the API specifications, message schemes, and other core standards, components can be swapped in or out over time. This approach also avoids vendor lock-in because no single vendor can hijack the interface. If a proprietary solution becomes problematic—for example, if it is too costly, the government can replace it with an alternative that is based on the same open infrastructure. This approach is commonly known as "protocols over platforms." That is, governments prioritize open protocols that anyone can implement, rather than relying on a single company's closed platform.

Fragmented or proprietary standards impose significant costs at the macro level. In Kenya, M-Pesa's decade-long dominance of the mobile money market meant that transfers between M-Pesa and rival wallets were cumbersome and expensive until the government mandated interoperability in 2018. Economic analysis conducted by GSMA suggests that the absence of a common rail decreased the volume of mobile money transactions by 25 percent–40 percent and decreased GDP growth by about 0.6 percent in Kenya (GSMA 2020). Similarly, in Nigeria prior to the adoption of the Central Bank's national standard for the quick-response (QR) code in 2022, banks and other financial technology companies each issued their own QR format, which increased on-boarding costs for merchants by about 30 percent and kept the use of QR codes very low (less than 1 percent of retail transactions). Within 18 months of the launch of the national QR code, volumes had tripled (Central Bank of Nigeria 2022).

Fragmentation also affects high-income economies. In the United States, proprietary electronic health record schemes means that hospitals must purchase costly interface engines and repeat diagnostic tests. A study conducted by the West Health Institute demonstrates that adopting the open FHIR (Fast Healthcare Interoperability Resources) API standard could save the United States $30 billion annually in administrative costs (West Health Institute 2013).

These examples demonstrate that when the core standards in the "thin-waist" connecting layer of the hourglass model are not unified, network effects stall, costs of integration rise, and innovation concentrates in dominant silos. Quantitative studies have estimated that middle-income economies forfeit a one-half to one percentage point increase in their GDP due to the fragmentation of standards (World Bank 2024b). By contrast, once a country mandates a clear, open standard (such as Kenya's wallet switch, Nigeria's QR code, or FHIR in the US health IT sector), markets converge quickly, costs decrease, and new entrants proliferate.

Decentralized initiatives like the Finternet make calibrated decisions on where to draw the line between the "core" that must remain open and areas where proprietary innovations can be layered without compromising interoperability or public control (Carstens and Nilekani 2024). The hourglass model for DPI (with a narrow waist of common standards and diverse implementation above and below) provides a useful example. Mandating openness in the "thin waist"—the critical connectors and definitions of data—ensures that the system can be extended to additional use cases and that it is competitive. Flexible options, including propriety offerings, can be introduced above the waist (applications) and below it (infrastructure), as long as they are compatible with the open core.

This balanced strategy acknowledges that at their core, public infrastructures should embed open standards by design, while leveraging the best available technologies (open or closed) to deliver services, provided those technologies do not create new silos. The World Bank and other actors have been promoting open-source DPI platforms (such as MOSIP for digital identification) to provide developing countries with a viable open alternative to proprietary offerings (OECD 2024). As these open platforms gain maturity, the calculus can shift toward favoring openness, even in settings with limited resources, provided they are accompanied by technical assistance. The G20's endorsement of open DPI standards suggests a strategic recognition that interoperability is a global public good, and emerging economies seek to champion it rather than leave it solely in the hands of standards development organizations in member states of the Organisation for Economic Co-operation and Development (OECD). For example, the European Commission and the United Kingdom adopted open document formats and web standards in government services to break the dependence on any one vendor. Therefore, the trend has been to favor adopting open interfaces in critical public systems.

Ensuring interoperability among systems and departments has an outsized influence on economies

DPI protocols and platforms often utilize technology and standards as building blocks for their implementation. In doing so, they sometimes knowingly or inadvertently develop entirely new standards. For example, Aadhaar mandated the use of hardware security modules (HSMs) compliant with FIPS 140-2—an internationally recognized security standard—for signing authentication XML and e-KYC decryption (Entrust 2023). For the implementation of the Aadhaar data vault, UIDAI adopted REST (Representational State Transfer) API standards—a widely used set of web service standards—for the solution developed by C-DAC (Centre for Development of Advanced Computing). UIDAI created detailed specifications for certified biometric devices and mandated that all biometric devices used for authentication be registered devices according to the UIDAI-specified standards to ensure that there was no vendor lock-in to one manufacturer of biometric devices (India, UIDAI 2021). Aadhaar's implementation of e-KYC has become a standard method for verification of identity in India's financial sector, replacing the older paper systems. Some studies have estimated that this standard has cut the processing time and costs by half (Banerjee 2016).

As open-source technologies become more prevalent and closely aligned with the needs of the market, they have the potential to replace formal standards. These projects can also evolve faster than formal standards, making them more responsive to fast-paced changes in technology and the changing demands of the market (Egyedi and Blind 2008). In addition, stakeholders from open-source communities developing governance models are adopting a community-based approach to governance that effectively manages the evolution of technologies, potentially replacing the role of traditional standards-setting organizations. This was the case of Ethereum and W3C, with intervention from central authorities or the regulator required only in critical infrastructure or public sectors (Fitzgerald 2006).

Considerations on cost often shape the debate on whether standards should be open or proprietary. Vendors of proprietary technologies may offer attractive deals initially, including sometimes free or subsidized pilots, in order to gain a foothold. But costs can increase for the expansion, customization, or annual licensing of the technology. Open-source technologies typically do not require a license, which can significantly lower costs, particularly when used at scale. For example, an open-source ID system would not entail individual fees for each user. In addition, open-source technologies avoid exposure to currency fluctuations or price increases, which is relevant for low-income countries that set budgets for multiyear projects. However, adopters of these technologies incur other indirect costs, such as hiring talented staff or paying for contracting support.

The pertinent question is whether these ongoing costs benefit the economy at the local level. Open-source solutions ensure that resources are invested in IT firms or staff at the local level, whereas costs spent on proprietary technologies often contribute to the profits of foreign vendors. Although it may not be apparent initially, there is a trade-off. With open standards and open-source technologies, governments can be “free-riders” on these global public goods, but they risk lacking any support if they are unable to contribute back. With proprietary technologies, users are paying for the service through a contractual arrangement, but these users are then also dependent on a single supplier.

Collective action can help mitigate the problem of free-riding. Multiple governments can jointly support crucial, open-source components of DPI. For example, coalitions like the Digital Public Goods Alliance (DPGA) pool resources to maintain open-source building blocks of DPI.[21] Ensuring that certain terms are included in the contract can mitigate proprietary lock-in, such as requiring escrow of source code, ensuring that the transfer of knowledge is directed to local vendors and staff over time, limiting the length of the contract, and undergoing a tender periodically to allow competition in procurement. Both open-source and proprietary solutions require smart governance.

In summary, openness is a foundational principle for DPI. While it maximizes the degree of interoperability and ensures high potential for innovation, it does not guarantee a pluralistic ecosystem or guarantee outcomes that are in the best interest of the public without other principles in place. Policy makers should ensure that no one stakeholder takes the entire market share and can thus capitalize on an open standard. If necessary, policy makers should introduce complementary policies (such as enforcing regulations on the sharing of data, promoting implementation of open-source references, or leveraging antitrust rules and regulations if a single firm starts to dominate an "open" ecosystem), or invest in capacity building so local firms can compete on the open standard. The aim of governments is to ensure that openness in standards leads to the desired outcomes of spurring competition, broadening inclusion, and maintaining sovereignty.

Global lessons from DPI at the end of the globalized era

The examples of successful experiences of countries implementing DPI showcased in this study are all largely based on the hourglass model—mandating a "thin waist" for technical specifications. But the successful implementation of DPI also requires effective collaboration between the public and private sectors to ensure buy-in and scalability. Low-income countries may face distinct challenges at the bottom of the hourglass, such as very limited digital skills, weak infrastructure, and constrained budgets. Middle-income countries and developed economies often have better technical capacity but may face issues resulting from legacy systems and entrenched interests. Their challenge is often around institutional coordination. Multiple agencies may have built their own systems in silos and therefore may resist the creation of a unified DPI standard. The context of each jurisdiction helps guide the selection of the "building blocks" for DPI, but there are important lessons from previous implementations of DPI that EMDEs can leverage as they upgrade or create their own infrastructure.

DPI standards can alter market power dynamics between the public sector, domestic firms, and influential global technology companies. DPI initiatives that intentionally aim to expand financial and social inclusion by reaching the unbanked, rural populations, and other marginalized groups are the most transformational. However, expanding financial and social inclusion does not guarantee a competitive balance between market participants. Firms will still compete on execution, and large platforms with advantages of scale can attract more users, even in an open ecosystem. The case studies in this study demonstrate that governments must play a role at various stages of the implementation of DPI, including establishing clear legal frameworks for the protection of data, electronic signatures, and digital payment systems. Many countries have established new regulatory units or updated their legislation in areas such as electronic transactions and data privacy in parallel with the roll out of digital identification and payment systems.

Good governance also entails collaboration between the public and private sectors, including leveraging private innovation while the government provides the core infrastructure and oversight mechanisms. For example, some governments provide a digital identification platform but allow banks and fintech companies to handle the day-to-day operations of the platform, including interactions with customers.

In addition, public trust is essential for the widespread adoption of digital identification and payments. Users must trust that their personal data are secure and that the systems will reliably protect them from fraud or misuse. Countries that have succeeded in widespread adoption such as Estonia and India invested heavily in cybersecurity and legal safeguards for privacy.

The governance model must also adapt to varying levels of trust. In environments where public trust is low, governments sometimes initially provide services directly in order to assure the public, whereas in environments with higher public trust, the private sector may drive solutions that follow regulatory standards. Multilateral institutions such as the OECD, World Bank, and International Monetary Fund (IMF) are currently working on promoting standards and principles to guide national policies in areas such as digital payment interoperability and verification of digital identification. Strong governance underpins the credibility of these systems, which in turn ensures that the systems generate sustainable benefits such as economic growth, efficiency, and reduction in fraud.

A recurring theme in successful digital ecosystems is interoperability across platforms and providers. Member states of the G20 and emerging economies are applying the hourglass model to their digital infrastructure in practice. At every layer of the DPI stack, designers should create each component in a way that it can be easily replaced in the future in order to hedge against obsolescence of technologies and vendor lock-in. This principle leads designers to build systems from modular components connected by standard interfaces (which also follows the internet hourglass model). If a module is currently proprietary, designers should ensure that in the future, an open-source or alternative proprietary module can replace it without the need to completely rebuild the system.

With digital identification systems, there has been a push to establish a single, universal identification system (the thin waist), but accompanied by diverse authentication methods and uses. Countries like Brazil and India have standardized the identification format and verification protocol nationally, enabling interoperability in verification.

With respect to digital payment systems, the most successful cases are explicitly designed around common rails for the clearing and settlement of payments (such as instant payment networks with shared rules), with vigorous competition among consumer-facing products. The broad uptake of UPI and Pix is a direct result of their open-access design that allows many providers to offer payments—but all through one interoperable interface.

The same principle is being followed with the exchange of data (although it is a more recent field). Countries are identifying key common standards such as formats of the data, exchange protocols, and security and consent rules that form the waist of the hourglass. By implementing these standards at a national level, they enable numerous cases of the sharing of data. For example, once Estonia adopted the X-Road standard, many government services such as tax, health, and the police could integrate into the data exchange system.

Finally, many DPI initiatives require changes in legislation and government support to succeed. While the local context varies by country, developing countries can benefit from first observing the legal and regulatory changes in advanced economies before taking any actions. The benefit of implementing DPI at a later stage is the ability to embed requirements for interoperability at the start of building the digital system. For example, in Brazil, more than 25 million people made their first-ever digital payment via Pix. In India, UPI has replaced cash in everyday transactions, including for street vendors. Other EMDEs that are members of the G20 are following suit. Malaysia's real-time DuitNow and Thailand's PromptPay have been widely adopted. In Mexico, uptake of CoDi (built on the SPEI system) was initially slow, partly due to lower penetration rates of the smartphone and weak marketing strategies. However, the volume of transactions is increasing as more banks and fintech apps integrate the QR system. South Africa learned from Kenya's experience and launched PayShap in 2023 as a low-value instant transfer service to broaden access of the digital payment service alongside its older real-time clearing system. While use of the system is still modest, with a few million transactions, South Africa anticipates that uptake will increase as more banks waive fees for small transfers and as mobile fintechs join.

In all of these examples, regulations have played a key role, with many of these countries seeking to adopt legislation on data privacy that is similar to the EU's General Data Protection Regulation (GDPR). Relatedly, countries around the world are adopting legislation similar to one another on digital assets.

A set of DPI "first principles" based on evidence and experience

This section outlines a set of principles to help policy makers in choosing and implementing standards in DPI, in evaluating trade-offs, and in adopting decisions that are appropriate to the local context, while aligning with the strategic goals of inclusion, innovation, and resilience.

1. *Prioritize standards that maximize interoperability* across systems, sectors, and borders. In practice, this entails favoring widely adopted open standards (or open APIs) for the core functions of DPI (the "thin waist" of the hourglass) because interoperability enables a wide range of services to be integrated into the system. For any proposed technology in the stack, designers should ask whether the technology "speaks a common language." If designers are considering a proprietary solution, they should ensure that it has adapters or interfaces that conform to open specifications to allow them to connect with other components. Relatedly, individuals and governments should be able to migrate data out of any system using standard formats in order to avoid silos. The design of interoperability guards against fragmentation and the creation of a monopoly. The "layering" approach requires that the foundational layers be highly interoperable. By leveraging inexpensive and modular components, DPIs avoid vendor lock-in and simplify implementation and maintenance, while promoting rapid innovation and adaptability.

   In the area of biometrics, for example, many countries align with international standards to ensure interoperability and accuracy. For example, Aadhaar uses the ISO/IEC 19794 series for fingerprint, face, and iris images, which allows biometric data captured in one system to be understood by another. Standards for data formats such as XML or JSON schemes ensure that data related to identity (such as names and addresses) can be exchanged consistently. For example, the International Civil Aviation Organization (ICAO) arrangements for e-passports cover both machine readable travel documents (MRTDs) and the logical data structure (LDS) (ICAO 2021). Interoperability is not an "all-or-nothing" choice: based on the hourglass model, the core "waist" should be kept open. A government may choose to adopt some proprietary tools at the top or bottom layers (such as specific applications or hardware), but should ensure that the core standards (such as the interfaces and protocols) are open.

2. *Choose standards and solutions that empower participation of the local ecosystem.* One measure of success for DPI is whether local companies, startups, and community organizations can build services on top of the core infrastructure. The local context of each country should determine the primary goals of the DPI. For example, lower-income countries typically emphasize affordability and sovereignty; thus, they prefer open and free standards. Middle-income countries and emerging economies emphasize the growth of local ecosystems and ensuring that large technology companies do not have an outsized influence; thus, they mandate openness in core systems. High-income countries emphasize innovation and integration; thus, they adopt open standards but allow evolution driven by industries. However, all countries generally adopt the view that some degree of openness in DPI is vital and that infrastructures that are entirely proprietary and closed carry risks, regardless of the context. Standards should therefore not be too complex or closed that only a few multinational institutions or companies can implement them. Standards that are simple, well-documented, and freely available lower the technical barriers for local developers.

Governments may also invest in open-source reference implementations or innovation sandboxes for standards to spur their adoption locally, such as providing an open-source library for a payments API. An inclusive approach to standards also entails involving local stakeholders in the selection of which standards to adopt and the process of adapting international standards to the local context. If a global standard does not fit the needs of the local context perfectly (for example, address formats or identity attributes), the government can adapt it to suit the local context, ideally contributing those modifications to the international standard community. By ensuring that a country adopts only those standards that it has the capacity to comply with or enforce, DPI can become a platform for domestic innovation, rather than only a consumer of foreign technology.

Countries occasionally create standards that are customized to the domestic context, such as Nigeria's domestic standard for electronic funds transfer (EFT) or the early internal format of M-Pesa in Kenya. In an ideal context, these standards would not pose hurdles when connecting to international systems or even integrating new domestic participants. However, emerging economies designing DPI for digital payments today typically choose to adopt ISO 20022 initially to "future-proof" their systems and ease integration into domestic markets and allow for its use across borders. For example, Brazil (with Pix) and Morocco (with its upcoming instant payment system) both chose to adopt ISO 20022 from inception, in contrast to India, which phased out ISO 8583 when implementing its UPI. Adopting ISO 20022 with Pix enabled its use for the transfer of cross-border remittances much more quickly.

Designers can implement interoperability through technical specifications such as web standards and API standards or within national or regional interoperability frameworks such as the EU's eIDAS (Electronic Identification, Authentication and Trust Services) regulation or the African Union's Interoperability Framework for Digital Identity.

Domestic interoperability within financial systems is increasingly recognized as a critical driver for economic growth and financial inclusion, particularly for micro, small, and medium enterprises (World Bank 2022a). For example, an African country implementing a digital payment system from scratch may prefer adopting an open-standard protocol like ISO 20022 and open-source software modules to enable domestic developers to build payment services into the module without needing proprietary connectors. The adoption of open standards also helps countries avoid recurring license fees, which in addition to the cost savings, also helps avoid fees being transferred to foreign firms. And reliance on proprietary technology translates into reliance on that firm's roadmap. Therefore, the preference of many developing countries for "technological self-reliance" typically aligns with the choice of open standards where feasible.

3. *Enact supportive policies to accompany technology standards. Such standards alone cannot guarantee a thriving, competitive ecosystem.* This principle calls for a holistic view. For example, if a government mandates an open standard for mobile payments, it should also be prepared to monitor the market and prevent any conduct that blocks competition (Kawale 2024). Openness can be undermined if, for example, one player uses predatory pricing or exclusive agreements to dominate an open network. Thus, competition policy, data governance (ensuring the sharing of data on fair terms), and even consumer protection (preventing proprietary lock-in through app stores or devices) come into play.

   The effective exchange of data in DPI requires both technical standards (common protocols, formats, and APIs for interoperability) and legal frameworks (policies governing privacy, security, and data sovereignty). Achieving the exchange of data on a national scale is challenging, especially amidst a trend of "data nationalism," which refers to the idea that digital information created within a country's borders should be stored, processed, and managed within that country.

Technology standards must also be accompanied by institutional and policy frameworks—the glue that ensures that DPI benefits development. Implementing DPI requires coordination across multiple sectors such as finance, telecom, and social welfare. Therefore, having a designated agency or coordination body that oversees DPI is crucial.

EMDEs often face constraints in technical capacity and must carefully sequence legal and regulatory measures alongside the rollout of DPI. Approaches to this coordination should account for the local context of each country. Some countries have created a dedicated digital agency or task force to promote and oversee the implementation of DPI, such as India's Goods and Services Tax Network (GSTN) for its tax DPI and Thailand's Digital Government Development Agency. Other countries embed it within existing institutions, such as having central banks implement and oversee DPI on payments and interior or IT ministries overseeing DPI on digital identification.

What matters is that the institution in charge has the mandate and technical expertise to set and enforce standards across different sectors. In lower-income countries, international partners may initially support such high-level coordination to ensure there is sufficient technical capacity, while still establishing local ownership through a permanent e-government unit or ICT ministry. Aadhaar's struggle in India's Supreme Court, which spanned five years, began in part due to the absence of a comprehensive law on privacy (Supreme Court of India 2017).

Divergent regulations on data protection and privacy across jurisdictions can hinder cross-border interoperability. For example, complying with both the EU's GDPR and China's Personal Information Protection Law increases operational costs for multinational corporations (Escobar 2025). Adopting regulations and legislative policies is an iterative process—governments can easily adopt existing frameworks and revise them following consultations with businesses and industries. Twinning arrangements—where a regulator from an advanced economy mentors one from a developing country—have been used effectively. For example, the Monetary Authority of Singapore has advised regulators from emerging markets in Southeast Asia on payment interoperability frameworks (KPMG 2018).

4. *Adopt open standards wherever feasible, but mandate openness in key interfaces.* This recommendation is based on the principle that DPI should be built on public goods. For example, criteria for procurement can explicitly include compliance with open standards such as requiring support for an open identity credential format or messaging protocol. Where multiple standards exist, preference should be given to those with more open licensing and governance.

   Openness by design also implies transparency—ensuring that standards are well documented and comprehensible to anyone with the required technical skills. This transparency reduces information asymmetry between governments and vendors. Even if certain components are proprietary, governments should negotiate rights that maintain the openness of the overall architecture, such as access to source code in escrow, or clauses that require vendors to adhere to evolving open standards adopted nationally.

There has been a lot of debate about the divergent approach adopted by Pix regarding instant payments compared with India's "gold-standard" UPI. The Central Bank of Brazil (BCB) built the central infrastructure (clearing house) that is a platform of sorts, but invisible to users. It also allowed interface with private apps via protocols to offer Pix payments to customers. BCB adopted this approach because they had noted that there were few incentives to pursue a market-driven solution that strives for global optimization and it has resulted in a truly scalable, cost-effective, and flexible rail (CTPI 2023).

Developing robust protocols requires technical capacity, which not all countries have. The approaches are not mutually exclusive, as seen in the case of India, where BHIM UPI, developed by NPCI, serves as a payment app that competes with private players like GooglePay and PhonePe. Further down the spectrum, governments adopting platform or proprietary approaches in order to build nascent ecosystems need to ensure that some elements of interoperability are either built in by design or through legislation.

In reality, many DPI initiatives combine both approaches. The choice of where to adopt DPI on the protocol-platform spectrum often depends on the maturity of the market and level of trust in the private sector. If the private sector is vibrant and capable, adopting a protocol approach can harness it. India had many startups ready to build on UPI. If the market is weak or there are low levels of trust issues, a government platform might be chosen, at least initially, such as when the market will only trust a government app to validate a vaccine certificate.

Conclusion

DPI has the potential to transform the development of countries, but realizing this potential requires governments to make careful choices about what aspects to standardize and where to allow flexibility. This study highlighted how the hourglass model can guide these choices: by establishing a few core common standards (the "thin waist"), countries can enable interoperability and broaden access, while still ensuring diversity and innovation to the applications above and the infrastructure below.

At the same time, context matters: there is no "one-size-fits-all" blueprint for DPI. Countries vary in their institutional capacity, level of private sector development, user needs, and legacy systems. An appropriate solution in one country may not apply in another. Policy makers should therefore use the hourglass logic as a guiding principle and ask, "Which elements will yield the greatest network effects and public good if they are developed as common standards?" Those elements would likely belong in the thin waist (for example, a format for national identification format, a payments interoperability scheme, or a data-sharing consent system). They should then ask, "Where is diversity and competition more valuable than uniformity?" Those elements belong in specific interfaces (for example, in user-facing apps, or in business process specifics for different sectors). By making these distinctions, policy makers can avoid the two extreme approaches: neither chaotic fragmentation (from failing to standardize what needs to be common) nor stifling uniformity (from overstandardizing elements that should be left to local innovation).

This study has emphasized the recurring theme of strategic openness: that is, knowing when to mandate open standards and where to allow adaptation. This theme is directly linked to the hourglass model, with a stable, open "waist" of core protocols and diversity above and below. The analysis of the spectrum of open standards and associated policies reinforces why the "waist" should be open as the only means to guarantee interoperability, avoid duplication of effort, and spur broad-based innovation. By keeping the critical layers of DPI are open (in both the technical and governance elements), governments ensure that they retain agency over the digital infrastructure. They are not locked into a single vendor or trajectory; they can adopt new technologies as they emerge, plug in new services, and integrate with global networks on their own terms.

At the same time, the study has acknowledged that open standards are not a quick and comprehensive solution, and proprietary technology is not always negative. The optimal design of DPI leverages the advantages of both elements. It uses open standards to establish the rules of the road, harnessing innovation (open-source or commercial) to implement those rules. This balanced perspective is what the hourglass model fundamentally encapsulates: a controlled center with freedom on the peripheries that can include proprietary innovations, as long as the center (the interfaces and data definitions) adheres to open, nonarbitrary standards. Governments can navigate the tensions between public and private interests in setting standards by adhering to principles that protect the public core through openness and interoperability while engaging the private sector for implementation and scale-up through collaboration and establishing clear rules of the game.

In conclusion, a strategy of open standards for DPI is not driven by ideology; rather, it is centered on achieving resilience and inclusiveness. Openness ensures that no single actor can monopolize critical infrastructure, that users have options, and that countries can interconnect seamlessly in the emerging digital economy. But openness must be managed through supportive policies and a clear understanding of constraints on the ground. If done right, the payoff is a DPI that is truly public in character, reflecting collective governance and shared benefits, and robust enough to evolve with technological change.

By setting standards with a principled yet pragmatic approach, governments can steer their DPI ecosystems toward greater inclusion, competition, and innovation, fulfilling the promise of digital infrastructure as a driver of sustainable development. The journey to open standards becomes a central part of building digital nations: a commitment to openness not as an end in itself but as a means to secure the future flexibility, equity, and interoperability of the digital foundations on which a society operates.

Notes

[1] *Grundnorm* (German for "basic norm") is a concept created by Hans Kelsen, a jurist and legal philosopher, to denote the basic norm, order, or rule that forms an underlying basis for a legal system.
[2] For more information, refer to https://www.undp.org/digital/digital-public-infrastructure and Clark et al. (2025).
[3] For more information, refer to https://asq.org/quality-resources/learn-about-standards.
[4] For more information, refer to https://www.nist.gov/standardsgov/standards-information-center.
[5] For more information, refer to https://www.ifrs.org/use-around-the-world/why-global-accounting-standards/.
[6] Refer to WTO (1994), Article 2, Paragraph 2.
[7] For more information, refer to https://dpimap.org.
[8] Until 2019, UPI transactions incurred a MDR charge of about 0.3 percent of the transaction cost. The government eliminated these fees to accelerate the uptake of digital payments in areas with lower economic activity. To compensate providers for the lost revenue in MDR charges, the government introduced a public subsidy of 15 basis points for each low-value transaction under Rs2,000 (about US$23), but it retained MDR for large-value merchants. The range of MDR is still orders of magnitude lower than traditional card fees, which typically are about 1 percent or more of the transaction amount.
[9] For more information, refer to https://pmjdy.gov.in/account.
[10] The Digital Personal Data Protection Act was passed by both houses of the Indian Parliament in 2023, but the Act has not yet come into force.
[11] GDP (gross domestic product) is measured in purchasing power parity (PPP), constant 2017 international dollars.
[12] For more information, refer to https://dpimap.org/.

[13] The Open Document Format for Office Applications (ODF), also known as OpenDocument, standardized as ISO 26300, is an open file format for word processing documents, spreadsheets, presentations and graphics and using ZIP-compressed XML files. It was developed with the aim of providing an open, XML-based file format specification for office applications.

[14] For more information, refer to https://www.iso.org/standard/79451.html.

[15] For more information, refer to https://www.iso20022.org/.

[16] The payback period refers to the time it would take for financial institutions to recover their initial investment in implementing either updated ISO 8583 systems or new ISO 20022 systems.

[17] Implementing ISO 8583 incurs a one-time cost of ₵2.1 billion with an annual net benefit of ₵389 million, which is equivalent to a 19 percent return ratio, resulting in an 11-year payback period. Implementing ISO 20022 incurs a one-time cost of ₵2.62 billion with an annual net benefit of ₵319 million, which is equivalent to a 12 percent return ratio, resulting in an 18-year payback period.

[18] The FCA Sandbox is a pioneering initiative designed to encourage innovation in the UK financial sector while ensuring consumer protection and market integrity. The purpose is to provide innovative technologies and financial solutions the necessary testing ground, regulatory exemptions and statutory support.

[19] For more information, refer to https://eips.ethereum.org/erc.

[20] A Layer 1 blockchain is the base network architecture that serves as the foundational infrastructure for a blockchain ecosystem, responsible for executing transactions, processing data, and maintaining consensus through its native protocols and consensus mechanisms. It provides the underlying security and decentralization for all operations and applications built on top of it. Bitcoin and Ethereum are prominent examples of Layer 1 blockchains, forming the essential backbone for their respective ecosystems and other developments.

[21] For more information, refer to https://www.digitalpublicgoods.net/.

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