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Equitable Development Transformation with Technology: Relevance of the Indian Experience for Global South

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Equitable Development Transformation with Technology: Relevance of the Indian Experience for Global South

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Abstract: The wider dimensions of technology and its deeper socio-economic impact are becoming more complicated as new technologies are revolutionising the inter-balancing of factors of production, particularly, labour and capital, leading to widening income inequalities across countries. Such outcomes could be attributed to skill-biased technological change and weak innovation and entrepreneurial ecosystems in developing countries. Moreover, the impact of technology needs to be analysed not only from an income perspective, but also from the perspective of Access, Equity and Inclusion (AEI). There has been low integration of widespread practices of inclusive innovations and inadequate support for pro-poor innovations. India, on the other hand, has experienced large scale development transformations in recent past with technology, leading to relatively equitable outcomes ensuring both access and inclusion. This paper attempts to capture the discourse exploring the potential role of technology as an equaliser in terms of addressing the concerns pertaining to inequality and eventually leading towards a development transformation which is equitable as well as inclusive. In doing so, the paper contexualises the theoretical context and measurement framework based on the ideas related to technology, inequality and welfare; inclusive innovation and AEI.

Keywords: Technology; Development Transformation; Global South; Inclusive Innovation, Digital Public Infrastructure.

Introduction

Technology has been a critical factor in the evolution of the society, and increasingly becoming more integral to our development process and its outcomes. The wider dimensions of technology and its deeper socio-economic impact are becoming more complicated as new technologies are revolutionising the inter-balancing of factors of production, particularly, labour and capital.

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The role of technology and its connect with growth and development, capital accumulation and inequality is a field, where varying perspectives have appeared since the days of classical economics. With the rise of specific technology-led systems, these debates have further narrowed down on their actual imperatives for output, capital, consumption and productivity. Since Rio+20, another factor of production added to the list is of resource base.

In the recent past, a wave of technological revolution has emerged across various fields, ranging from life and biosciences to information and communication technologies (ICTs). Internet revolution and web-based resources and services have opened up many opportunities, resulting in a paradigm shift in production and consumption of goods and services. On the other hand, the growth and expansion of global value chains (GVC) has transformed trade, manufacturing and services. Worldwide, on account of such developments and convergences among technologies, the twenty first century has seen phenomenal changes in the way Science, Technology and Innovation (STI) is perceived and understood. India is no exception to that as India started its development journey in 1947 making STI as a tool for socio-economic development and national transformation which continues with accelerated speed and greater ambitions now.

In view of these developments, this paper attempts to capture the discourse exploring the potential role of technology as an equaliser in terms of addressing the concerns pertaining to inequality and eventually leading towards a development transformation which is inclusive. In doing so, the paper draws from the successful Indian experience in leveraging technology in bringing in such transformation while citing instances from across some select sectors such as banking/finance, health, agriculture, and energy that have successfully leveraged India's major leap in Digital Public Infrastructure (DPI).

In this context, Section II discusses the issues and findings with regard to impact of technology on welfare in general and its broader impact on the society. It also elaborates on the theoretical underpinning and conceptual background on inclusive innovation. It contexualises

Access, Equity and Innovation (AEI) as a methodology for assessing and measuring equitable and inclusive development transformation unleashed through new technology paradigms like the DPI. In order to capture the various dimensions of such large scale transformation as well as to identify measurable parameters for a relevant assessment framework-based on AEI, Section III elaborates on the principles, modalities and outcomes of implementation of DPI in India across select sectors like agriculture, health, banking and finance, and energy. Section IV concludes by synthesising the key findings and draws upon the relevance of Indian experience to suggest possible way forward for the Global South.

Inequality and Technology: Theoretical Context and Measurement Framework

The welfare implications of technological changes have been predominantly analysed from the perspective of impact on labour. With the rise in informalisation of work, rise in unemployment (various forms of disguised employment/underemployment) and eventually rise in inequality in societies across the world, the impact of technology is being analysed from an income perspective as access and equity are being seen as twin objectives for technological change to accomplish. The exclusions that are happening have been analysed in the economic literature as Skill-Based Technological Change (SBTC).

Technology, Inequality and Welfare

Solow (1957) demonstrated that income inequality is worsened when the direction of a production technology favours skilled labour over unskilled labour by increasing its relative productivity. Capital accumulation may also change the marginal productivity in favour of skilled and qualified workers if physical and human capital is technological complements. Several papers by Galor and Tsiddon (1997) have given evidence to this effect. According to Grossmann (2001), "new technologies cause a shift in the production function which contains high skill and low skill labour as arguments, such that the relative marginal productivity rises, leading to a rise in demand for skilled labour and if wages are flexible, then there is a rise in wages for skilled labour, given relative labour supply."

Inequality and growth literature has largely evolved around two tracks. As per to Grossmann (2001), the first set of literature has concentrated on the impact of capital accumulation and technological change on the distribution of income and wealth, whereas the second set of literature has focused more on the impact of inequality on the rate of growth. Here, we are concerned more about the first category, where, Adam Smith and David Ricardo put emphasis on functional income distribution (see Kurz 2010 for more details). However, contemporary economic developments have focused more on income inequalities. Pen (1971) notes:

> In functional distribution, we are no longer concerned with individuals and their individual incomes, but with factors of production: labour, capital, land and something else that may best be called 'entrepreneurial activity'. The theory examines how these factors of production are remunerated. It is primarily concerned with the price of a unit of labour, a unit of capital, a unit of land, and being therefore an extension of price theory. It is sometimes called the theory of factor prices.

Concern with the equity outcomes of innovation goes back to the 1950s. Building on Schumpeter's original ideas, Zweimuller (2000) points out the following:

> In the standard Schumpeterian growth models income inequality plays no role because consumers have homothetic preferences. By assumption, the level of demand for the various goods - including the innovator's product - does not depend on the income distribution. While the assumption of homothetic preferences has turned out convenient in incorporating monopolistic competition into a general equilibrium framework, it is highly questionable from an empirical point of view. The long-run growth rate depends on the distribution of income because it affects the time path of demand faced by an innovator. If current innovators expect a high future innovation rate they have an incentive to conduct more R&D today. These complementarities are results of the fact that innovations drive growth and that the economy wide growth rate has a positive impact on the evolution of an innovator's markets.

Chataway *et al* (2013) identified four major strands of analysis in the emerging area of inclusive innovation viz. the impact of growth paths on innovation and inclusion; the dynamic of not-for-profit and community-based "innovation from below"; the Schumpeterian motor and profit seeking innovation i.e. "innovation from above"; and the call for innovations in public goods, including those involving public private partnerships. They have also identified three key sets of actors in the development, promotion and diffusion of inclusive innovation. First one is the private sector (driven by Schumpeterian-motor), wherein, the for-profit firms (whether large, medium or small sized) were increasingly getting engaged in the production of their inclusive innovations, targeting low-income populations.

Such shifts towards low-income markets by the firms bear influence of the seminal work of Prahalad and Hart (2002), wherein they have argued that "low-income markets presents a prodigious opportunity for the world's wealthiest companies to seek their fortunes and bring prosperity to the aspiring poor". The second set belongs to the not-for-profit actors, who have been the primary drivers of inclusive innovation. Examples include community-based organisations working at grassroots levels such as the Honeybee network in India and large not-for-profit funds such as Gavi, which have predominantly focused on public goods. The third set of actors is the government, which is driving inclusive innovations through various policy interventions.

Science, Technology and Society

Studies of technology have not been confined to the disciplinary boundaries of economics alone. In recent years, social sciences, in particular, sociology has supplemented the efforts in economics and public administration to analyse the role technology is playing in science-society connect. Technological determinism is an attractive theory that gives the primary role to technology and institutions that develop and control technology. Ellul (1964) espoused the view that technology has a power of its own and with an internal logic that predetermines the outcomes and the impacts.

While exploring the impact of socio-political context on the development and deployment of technology, Winner (1980) famously asked "Do Artifacts Have Politics?" and answered in the affirmative. He argued that technologies can be inherently political in two forms. First, technologies can be designed or arranged, consciously or unconsciously, so that it can become a way of "settling an issue in a particular community". To substantiate this, Winner claimed that New York master builder Robert Moses deliberately designed the construction of low-hanging overpasses and bridges in certain parts of the city to keep-off public transport mediums such as buses (which were used mainly by poor and black people) from plying in those parts (which were inhabited by white upper class people). Kranakis (1996), while researching on American bridge builder James Finley and French engineer Claude-Louis-Marie-Henri Navier, too argued that 'social environments' shaped their engineering practices and the suspension bridges they built.

With regard to the issue related to gendering of technology, Cockburn (1999) argued that industrial, commercial, and military technologies were masculine in a very historical and material sense. She argued that technology "is one of the formative processes of men" and the appropriation of technology by men, and the exclusion of women from many of the domains deemed technical, were processes that leave their mark in the very design of tasks and of machines. Thus, the research in STS or sociology of S&T and related sub-disciplines has gone beyond extreme positions of technological determinism and technology as a neutral force/system.

These studies show that technologies can be designed from various perspectives and associated values and interests. In order to know the impact of a technology it is imperative to unpack the design of the technologies as the design incorporates designer's values, meanings and interests which could decide on who will have access and by restricting access it excludes people. Making an exclusive and iniquitous technology more equitable and inclusive after it is introduced often leads to limited success. Therefore, the values of equity and inclusion should be built into the process of design itself so that it takes care of Access, Equity and Inclusion (AEI).

There are different approaches ranging from Social Construction of Technology (SCOT), Actor-Network Theory (ANT) to co-production, Socio-Technical Systems, socio-technical imaginaries to study technology and its impacts/implications (Bijker *et al*, 1987; Latour 2007; Jasonoff, 2004). On the other hand, the economic theories and literature on technology has spawned a diversity of approaches in analysing development of technology, innovation and institutions and technology adoption/diffusion. A key feature of these approaches/theories is that some of them link technology with economic growth and distribution and with socio-economic gains, costs and benefits and directing technical change to meet some objectives. Moreover, the idea of ethics in this respect is also significant. Measuring AEI through indicators is a challenging task given the methodological issues, data availability and other issues in developing indicators. In giving importance to AEI, we are not taking the position that values like autonomy are irrelevant. Rather in our view, AEI is more relevant than abstract values like autonomy, freedom and human dignity. In this regard, it needs to be pointed out that inclusive growth and social inclusion are now part of the development economics literature and economists are developing indicators to measure them.

Foster and Heeks (2013) argued that conventional views of innovation (often implicitly) understand development as generalized economic growth, whereas, by contrast, inclusive innovation explicitly conceives development in terms of active inclusion of those who are excluded from the mainstream of development. Thus, they referred to inclusive innovation as “the inclusion within some aspect of innovation of groups who are currently marginalised”.

Various scholars and institutions have defined inclusive innovation and the underlying dimensions and approaches in the last few decades. Related terms such as ‘grassroots innovation’, ‘frugal innovation’, ‘reverse innovation’, ‘Jugaad innovation’, ‘Bottom of the Pyramid (BOP) innovation’, ‘Gandhian innovation’, ‘pro-poor vs. from-the-poor innovation', 'long tail and long tailoring innovation', and 'below-the-radar innovation' have also proliferated in abundance (Chataway *et al*., 2014; Kolk *et al*., 2014; Levidow and Papaioannou, 2017; Pansera, 2013; Sonne, 2012). Interestingly, the term 'inclusive innovation' was first used in 2007 in a World Bank report titled "Unleashing India's Innovation: Towards Sustainable and Inclusive Growth", wherein it referred to inclusive innovation as knowledge creation and absorption efforts most relevant to the needs of the poor in India (World Bank, 2007).

Schillo and Robinson (2017) have argued that there are four dimensions of inclusive innovation i.e. who, what, why and how, along which innovation needs to be inclusive. 'Who' is about people or groups included (such as disadvantaged, marginalised, excluded, poor, or 'bottom of the pyramid'); 'What' refers to the types of innovation activities included (such as funding, credit); while 'Why' is about capturing the broad range of outcomes and benefits (including economic, social, health or environmental) and 'How' implies the governance mechanisms on inclusion (through public innovation policies, schemes, initiatives). It is not always necessary that technology has to be high end, when we think of its introduction for mass adaption. Khosla (2003) offers an unorthodox perspective of the concept of leapfrogging in technology. He points out that:

> Leapfrogging can be relevant for technologies that enable creating livelihoods and to meet basic needs also, in addition to space technologies and biotechnologies. Technological leapfrogging does not mean considering only technologies like automobiles but also technologies that are energy efficient, lessen the burden of women in villages and hence suggests that they can be perceived from the perspective of a villager in India, which calls for favouring piggy back technologies over copy cat technologies.

Inclusive Innovation

Weak or underdeveloped innovation systems constrain the full utilisation of the potential of the technologies and their further development and diffusion. In order to understand the role of technology as an equaliser, the conceptual framework based on inclusive innovation would be pertinent as it emphasizes and promotes the creation of products and services that are specifically designed to meet the needs of low-income and excluded groups ("innovation for the poor") as well as encompasses the innovation carried out by the low income and excluded groups ("innovation by the poor"). From an Innovation Systems perspective, technology or technical systems do not make sense if not studied as part of a systems approach. In this perspective, the linkages among technologies and technical systems with the innovation system are critical to make any assessment of the role of technology. The new growth theory based on the relevance of systemic innovation approaches, is famously attributed to Rosenberg, Nelson, Freeman and Pavitt. They established the variants of the innovation system and associated policy options.

Heeks *et al* (2013), while deciphering different views on inclusive innovation, elaborated a 'ladder of inclusive innovation', which is nothing but a set of steps, with each succeeding step representing a greater notion of inclusivity in relation to innovation. This ladder consists of six levels namely intention, consumption, impact, process, structure and post-structure. According to Level 1(*Intention*), an innovation is inclusive if the intention of that innovation is to address the needs or wants or problems of the excluded group, while at Level 2 (*Consumption*), an innovation is inclusive if it is adopted and used by the excluded group. This requires that innovation be developed into concrete goods or services; that these can be accessed and afforded by the excluded group, and that it has the motivation and capabilities to absorb the innovation. At Level 3 (*Impact*), an innovation is inclusive if it has a positive impact on the livelihoods of the excluded group. That positive impact may be understood in different ways. More quantitative, economic perspectives would define this in terms of greater productivity and/or greater welfare/utility (e.g. greater ability to consume). Other perspectives would define the impact of innovation in terms of well-being, livelihood assets, capabilities (in a Sen-ian sense, Sen, 1993). At Level 4 (*Process*), an innovation is inclusive if the (members of) excluded group are involved in the development of the innovation. At Level 5 (*Structure*), an innovation is inclusive if it is created within a structure that is itself inclusive; while at

Level 6 (*Post-Structure*), an innovation is inclusive if it is created within a frame of knowledge and discourse that is itself inclusive.

Box 1: Inclusive Innovation: Conceptual Framework

According to UNESCAP (2018), inclusive innovation comprises initiatives that serve the welfare of lower-income and excluded groups and it includes both, "technological innovations" and "non-technological innovations". Technological innovation implies the creation or redesigning of a technological product, which is affordable and accessible to the poor and excluded sections of society; while non-technological innovation would imply the reorganisation of delivery system so that affordable technological solutions reach those poor and excluded sections. Inclusiveness can be articulated on the basis of three key dimensions i.e. social, economic and geographic. Social dimension includes women, low-income groups, persons with disabilities, older persons and other vulnerable groups whereas economic dimension is about ensuring that micro-, small and medium sized enterprises can fully participate in economic activities. Geographic dimension is about reducing disparities within and between countries and between rural and urban settings.

Fostering inclusive technologies and innovations could lead to multiple advantages. First, inclusive innovation can help build more resilient economies by enabling broad-based growth. Second, it can play a key role in ensuring social welfare and social justice by increasing opportunities to make goods and services available to low-income and other marginalised groups and by enabling marginalised groups to take part in innovation activities.

Source: Author compilation.

Thus, inclusive innovations and technologies provide a broader productive base and additional opportunities for economic growth. Inclusive technology and innovation can be supported through a myriad of approaches, which can be classified into the following four broad areas:

- *Strategic Approach*: It provides direction to the development of technology and innovation (such as through Government Flagship Missions etc)
- *Participatory Approach*: By promoting inclusive technologies and innovations coming from below (Innovation from Below/Gandhian innovation (Appropriate Technology, Grassroots Innovation and Open Source)
- *Capability Approach*: Fostering and promoting innovations which lead to the enhancement of capabilities (drawn from Sen's capability approach (Sen, 1993)
- *Approach for removing the barriers*: Particular groups (such as women, PwD, SC/ST, BoP etc), face as producers and consumers of technology and innovation

In the case of India, all the four above-mentioned approaches towards supporting and promoting inclusive innovation can be observed in select sectors such as health, agriculture, banking/finance, and energy. This conceptual framework based on inclusive innovation coupled with the analytical approach based on Access, Equity and Inclusion (AEI) can be deployed to analyse the role of technology as a means for bringing in an equitable and inclusive development transformation.

Framework based on Access, Equity and Inclusion (AEI) and Harnessing New Parameters

Technology is emerging in many ways as an equalising factor or tool, that can make a difference in terms of access, equity, and, inclusion. Equaliser does not mean that technology is the panacea for all problems, nor is the solution to all issues related to various inequities and inequalities. It means that technology provides an opportunity to equalise and is mediated by a host of factors, ranging from cost to availability. Therefore, it is imperative to examine inequality from a holistic perspective. Income or consumption expenditure-based estimates of inequality which are often considered for economic decision-making are measure of inequality at a certain point in time. There is a need to improvise the measurement of inequality based on the ensuing technological changes that adequately capture the dynamics in the reduction of inequality.

For instance, the initiatives on financial inclusion cannot yield instant or short-run measurable impact on the economic well-being of the beneficiaries but they plant the seed for a transformative change in their economic empowerment. Hitherto, the rural and poor households were mostly excluded from the formal banking system for lack of creditworthiness and absolutely no collateral to offer. Moreover, direct and timely delivery of public services such as farmer incentives, subsidies and pensions, etc. through IT solutions are noteworthy developments in reduction of economic vulnerability of the people; thereby causing a strong positive impact leading to the reduction in the level and incidence of inequality.

It can be argued that the dimensions, approaches and elements of inclusive innovation can be analysed by a framework based on Access, Equity and Inclusion (AEI). Access to the benefits of advances in S&T and deriving the benefits of technological advances is important. Access is often studied in terms of access of certain groups/classes to technologies and/or access to goods and services like drugs and how race, gender, etc. affect access to technologies particularly digital technologies and related services, and/or participation in science; while inclusion can be discussed in the context of exclusion and on the inclusiveness based on the dimensions related to social, economic and geographic. Equity refers to fairness and justice in the distribution of resources, opportunities and privileges, taking into account the unique circumstances and needs of individuals, groups or communities. It recognizes that different individuals or groups or communities may require different levels of support to achieve a level playing field. Equity aims to address historical and systemic disadvantages and achieve 'equality of opportunity'. Thus, equity goes much beyond equality, which is basically concerned about treating everyone in the same way and providing the exact same opportunities and resources to all individuals or groups or communities. Thus, access and equity are linked with inclusion.

Though AEI has been defined before. Writing the free form along with abbreviations repeatedly does not work nice as principles can be used for policy analysis and studying the impacts of STI policies, there is also an obvious need for robust indicators. However, the present indicators of impacts of STI, or innovation indicators do not take into account AEI nor consider them as important values to be measured. In development economics, it is being attempted to measure inclusion and exclusion and to study marginalisation or marginality. By aggregating multiple indicators using Principal Component Analysis (PCA), Chaturvedi *et al* (2015) developed two indices namely S&T Index and Social Index. An attempt to identify AEI related indicators with reference to select sectors such as health, agriculture, banking/finance and energy have been identified in this paper (Annexure 1). The PCA for formulating AEI index has also been given in Annexure 2.

AEI framework envisages criteria to measure the effectiveness of S&T policy. It brings in the framework of both qualitative and quantitative indicators on distributional aspects of innovation. Access is significant because often, for many reasons, the innovations do not reach those who require it most or accessibility is not thought to be part of production and distribution-related inequalities. Further, access is more than a matter of cost or affordability. Equity means innovations are equitably shared and are different from equality. Inclusion denotes that all those who require it are covered by the processes and mechanisms for which they are entitled to. Thus, AEI framework is more than a framework that deals with distribution or impacts. It is an ethical framework that links entitlements with needs, so that ultimately entire society benefits from it (Chaturvedi & Srinivas, 2015). The framework may help take societal interventions to meaningful and inclusive technological interventions.

AEI is also closely related to justice, fairness and equality, so there is good scope to examine it from disciplines like ethics, political philosophy and law, drawing upon the work done on foundational ideas and concepts on justice, fairness and equality. Another approach could be to link AEI with Right to Science. UNESCO has pointed out "Currently, this right to science is being undermined by two worrisome trends: the persisting inequalities of access to scientific knowledge and the applications of scientific progress".[1] Examining the societal impacts of emerging technologies in terms of AEI offers much scope for research and policy.

Leveraging Technology for Equitable Development Transformation

Harnessing the technological revolutions to facilitate greater Access, Equity and Inclusion (AEI) in India has enabled large scale development transformation which is a remarkable story with greater implications, for emergence with equity in the Global South. The modality to accomplish this objective has emerged largely through Digital Public Goods (DPG) and Digital Public Infrastructure (DPI). DPIs are at the heart of citizen centric development for delivery of welfare schemes through direct benefit transfers, creating knowledge networks, deeply enabling financial inclusion for all citizens and small businesses, facilitating world's largest traffic of digital payments among others.

One essential feature of India's approach particularly in DPI relevant for Global South is the middle path between over reliance on market forces and tighter control and over regulation by the state in deploying DPI and creating an enabling ecosystem. This is highly compatible with UN's Digital Compact philosophy and is antidote to digital exclusion and exclusion by market forces.

There are two important factors that have contributed to the success of DPI in India namely Platformisation and Data Democratisation.

a. Platformisation

DPI operates through platformisation. This implies launching of public digital platforms across different sectors for government and citizen engagement and for delivery of citizen-centric services, which has also led to generation of new employment opportunities and an ecosystem for start-ups.[2]

With low cost and interoperability, the large scale adoption has become possible through unique biometric identity for every citizen i.e.

Aadhar. Since the launch of Aadhar, India has many successful examples of DPI including, Unified Payment Interface (UPI), CoWin, Unified Health Interface (UHI), Ayushman Bharat Digital Mission (ABDM), and Open Network for Digital Commerce (ONDC). These platforms are operational in many sectors ranging from health to commerce while UPI has revolutionized payments system in India. UPI has enabled a seamless transfer of funds at zero costs and with a greater convenience. Many DPIs are in different stages of planning and implementation and are expected to transform access in many sectors, making inclusion and equity enabled by technology as a reality.

> As pointed out by Sharma (2023), India's approach to DPI is a beautiful blend of scalability, interoperability, innovation, and frugality. It's more than a technological advancement; it's a vision for a digitally inclusive future that resonates not only within the nation but also on the global stage. The India story of DPI is a testament to the country's commitment to leveraging technology for the greater good, setting a precedent for other nations to follow.

Interestingly, UN'S approach to Global Digital Compact stresses the importance of DPI as a key component of this Compact.[3] India is ahead in terms of theory and practice in DPI. While UPI as a model has gained adoption outside India, the larger impacts of India's approach to DPI will be more prominent in the future as India's DPI model can facilitate in fulfilling the objectives of UN's Digital Compact and in achieving SDGs. According to ITU and UNDP,

> Accelerating progress toward the Sustainable Development Goals (SDGs) requires inclusive digital transformation. Digital Public Infrastructure (DPI) can maximize the opportunities for digitalization to support the SDGs and reduce the risks that digital technologies may bring. Rather than taking a siloed approach to designing and implementing digital solutions, DPI emphasizes people-centered and interoperable digital building blocks at a societal scale. This approach allows local digital ecosystem players to innovate on top of these blocks, fostering new services for people. [4]

Digital public infrastructure (DPI), as an evolving concept and as a set of shared digital systems, built and leveraged by both the public and private sectors, based on secure and resilient infrastructure, and can be built on open standards and specifications, as well as open source software can enable delivery of services at societal-scale. During India's 2023 G20 Presidency, the G20 Framework for Systems of Digital Public Infrastructure was announced as a voluntary and suggested framework for the development, deployment and governance of DPI. India has also announced its plan to build and maintain a Global Digital Public Infrastructure Repository (GDPIR), a virtual repository of DPI, voluntarily shared by G20 members and beyond and has also proposed creation of the One Future Alliance (OFA), a voluntary initiative aimed to build capacity, and provide technical assistance and adequate funding support for implementing DPI in LMICs.

b. Data Democratisation

New technological solutions especially IT solutions are not only changing the governance landscape in India but also empowering the poor and the less advantaged in novel ways which has transformative impacts on their socio-economic conditions. DPI based platformisation and democratization has played a key role in this. The platformisation resulted in democratization of data by widening access and participation, by facilitating empowerment and all this in a scale never done or achieved before. The other positive outcome is building databases and data aggregators that can serve the needs of the citizens better and efficiently. With rules-based on India's Data Protection Act in place, concerns relating to privacy, data (mis)use are to be addressed.

India's approach to DPI helps us to understand this better and shows that AEI can be facilitated by deploying technologies on a wider scale by harnessing technological revolutions. In this context, during Indian Presidency of the G20, a new set of G20 High Level Principles on Harnessing Data for Development (D4D) to Accelerate Progress on the SDGs was accepted by G20 leaders. The principles incorporate strengthening data-informed approaches to sustainable development; enhancing high-quality data and sustainable data infrastructure; bridging the digital divides, including gender digital divide and growing data-divide; increasing financing and technology assistance; promoting inclusive use of data for development. Further, the G20 welcomed India's decision to launch a voluntary "Data for Development Capacity Building Initiative" for providing capacity building training for policy-makers, officials and other relevant stakeholders from developing countries.

Radical innovations in the digital space and paradigm shifts are becoming more frequent in these days, resulting in cascading effects. In such cases the role of technology as an equaliser is often not foreseen, nor even planned for when it is introduced or commercialised. It is in such contexts we need concepts like leapfrogging to understand and analyse the potential to equalise. Because technological leapfrogging creates new avenues without the need to go through the previously tried and tested paths in adoption and diffusion and enables the development of a new milieu for all aspects related to a technology or sector. Innovation systems perspectives are useful in understanding these.

A relevant example is the development and adoption of solar photovoltaic technology which heralds a paradigm shift in energy generation, diffusion, consumption and storage. This is obviously a disruptive innovation now, because although the technology is old, technological advancements have enhanced its efficiency, made wider adoption affordable and accessible and with all the economics and scale of technology underwent a drastic change. This is nothing short of a great leap forward in the energy sector. But more importantly it also brought in a change by blurring the lines between production and consumption and between producer and consumer by enabling closer feedback loops.

As we will argue later, this is an excellent example of technology as an equaliser. Whether technology is scale neutral is a key issue when we talk of technology as an equaliser. This question can be addressed better if we analyse technology diffusion and adoption and evolution of/

in technology over a period as technology also has generations. While there is continuity, there is also change, disruption and transformation in technology. For example, genetic revolution in agriculture is a continuation of green revolution in agriculture and recent developments like genome editing are continuation of the genetic revolution in agriculture. This means that while the equalising potential of technology may vary across generations of technology, it is better to avoid technological determinism in discussing technology as equaliser or as an equalising force.

Success Stories from Across Select Sectors

In the banking and finance sector, IT-enabled financial technologies (FinTech) offer tremendous opportunities to bring people out of poverty trap and inequality by addressing structural impediments in the provision of credit and promoting income-generating activities.

Table 1: Key Public Digital Platforms in Select Sectors in India

Banking and Finance	Health	Agriculture
UPI	Co-WIN	eNAM
IMPS	eSanjeevani	mKisan
AePS	Aarogya Setu	

Source: Compiled by the author.

These contribute to socio-economic development through financial empowerment. Using FinTech for transfer of funds between person to person or among business to business is an easy low hanging fruit. But using FinTech for widening and deepening access to credit and facilitate savings by the poor is a daunting challenge. India addressed this by banking on Aadhar and use of Aadhar enabled DPI which helped in overcoming multiple bottlenecks including making the poor to visit bank branches or ATMs to avail the benefit. Table 1 captures some of the details in all the three sectors while the Table 2 brings out the nature of coverage.

Table 2: Key Statistics Related to Select Public Digital Platforms

Public Digital Platform	Key Statistics
UPI	• No. of Banks Live on UPI: 598 • Total Transaction Volume: 14.03 Billion (*for May 2024*) • Total Transaction Value : INR 20.44 Trillion (*for May 2024*)
IMPS	• No. of Member Banks: 875 • Total No. of Transactions: 557.70 Million • Total Value of Transaction: INR 6.06 Trillion
Co-WIN	• Total No. Vaccination Doses Administered: 2.2 Billion • Total No. Registrations: 1.1 Billion
eSanjeevani	• Total No. of Patients Served: 25.5 Crore
eNAM	• Total No. of Mandis Integrated: 1389 • Total No. of FPOs Registered: 3803 • No. of Farmers Connected: 18 Million • Total Trade Value: INR 3 Trillion

Source: Compiled by author based on official websites.

Under the Pradhan Mantri Jan Dhan Yojana (PMJDY), as on date, 52.39 crore beneficiaries have been banked through Aadhar-enabled digital platform with a total deposit of INR 226,814 crore. Further, 11.59 lakh Bank Mitras are offering branchless banking services in areas with limited banking access. Interestingly, 34.87 crore (65 per cent) accounts are in rural/semi-urban areas and 29.13 crore account holders are women. In terms of deposits, the average deposit per account has more than doubled from INR 1064 in March 2015 to INR 4069 in August 2023. Pradhan Mantri Jan Dhan Yojana (PMJDY), a National Mission for Financial Inclusion, which completed nine years of successful implementation in 2023, is a remarkable testimony to what technology (w.r.t JAM Trinity i.e. Jan Dhan Accounts, Aadhar and Mobile) coupled with right policy intervention can deliver. PMJDY has brought the unbanked into the banking system, expanded the financial architecture of India and brought financial inclusion to almost every adult.

Likewise, significant growth has been observed in digital payments and RuPay card usage signaling a smooth journey towards a cashless economy. Both BHIM and UPI, indigenously developed payment gateways, have revolutionalised financial intermediation and payment ecosystem in India. BHIM and UPI have benefitted millions of small traders, artisans, service providers, vendors and others who were earlier not well covered by the banking and financial system. BHIM and UPI have been made accessible by many service providers like GPay, Phonepaye and PayTM and adoption of them by many players in the FinTech ecosystem have enabled easy and fast access to and availability of financial services including payments and transfers. This has now expanded to cover many other services ranging from payment of electricity bills to insurance premium.

The Government of India facilitated development of an ecosystem that is based on harnessing DPI by multiple players and others. This has resulted in innovations developed by inter alia, start-ups including aggregators. The next steps could enable wider and better access as well as increased efficiency in using DPI for more purposes that what is in vogue now. For example, with the Aadhar platform, the new technologies like Artificial Intelligence, Blockchain, Big Data, Cloud Computing, etc. would further ease access to formal banking services and other services and access to goods to all sections of the society. The DPI based ONDC (Open Network for Digital Commerce) is set to revolutionize ecommerce by challenging the dominance of a few players and by providing more access to markets and customers to a whole range of artisans, MSMEs and others and at affordable costs. This model reduce their dependence on a few players and benefits the consumers too. Thus by acting as an intermediary ONDC brings them closer without making them pay exorbitantly for access or for using its services.

Similarly, under the Pradhan Mantri MUDRA Yojana (PMMY) a good number of small and medium enterprises have befitted in the last five years. By filling the funding gap in a structured fashion, PMMY could have long term effects in promoting entrepreneurship especially in the SME sector. The shares of special category borrowers such as SC, ST, OBC, women and minorities have registered significant growth. During 2023-24, under PMMY, total amount of 5.41 lakh crore was sanctioned (disbursement of 5.32 lakh crore) in 6.67 crore loan accounts, which has helped in extending the much needed financial support to the poor entrepreneurs who are mostly from the weaker sections of the society, viz. SC/ST/OBC/Women in large numbers. In 2022-23, the participation of under-privileged sections of the society in PMMY was 51 per cent in terms of number of loan accounts and 37 per cent in terms of loan amount.

Another innovative financial inclusion programme which is being effectively implemented through digital platforms is the SHG-Bank Linkage programme. This programme has been contributing substantially to inculcating saving habits among poor families and enables them to convert their small savings into productive income-generating activities with the support from the commercial banks under the linkage. While all the three schemes on financial inclusion mentioned above do not addressing inequality in the short-run, the enhanced access to credit and business facilitation services by the government through digital platforms, the poor and vulnerable sections of society are better positioned today unlike the past to improve their standard of living. Likewise, through Direct Benefit Transfer (DBT) initiative the government is now able to transfer cash benefits like wage payments, subsidies and other government transfers directly into the bank accounts of the beneficiaries through electronic payment systems. It has resulted in minimising delays in fund flows, parking of funds along the delivery chain, and curbing leakage and duplication. Three major schemes – MGNREGA, LPG subsidies and pensions account for 90 per cent of funds transferred through DBT.

Today, agriculture is moving in the direction of precision agriculture in which AI, data analytics and ICTs will play a key role. However, it is important to note that adoption in agriculture has been very uneven and despite the Green Revolution and post-Green Revolution developments in technology, many farmers use a combination of generations of technologies while many still use livestock in agriculture for ploughing, etc. Moreover, whether technology has been an equaliser or equalising force in agriculture is a question for which there are no unambiguous answers. In the case of Green Revolution, studies indicate that although farmers with large land holdings benefitted more, small scale farmers also gained. The impact was strong as it helped millions of farmers to move from subsistence farming towards producing surplus and to be able to sell it. This economic surplus, in turn, facilitated capital accumulation and investment, and enhanced the standard of living. By this it set right some of the earlier inequities and enabled them to not only upgrade their living standards but also ensured that they could continue to gain as long as they adopted modern technologies. This in turn was made possible because technology was adapted with seeds developed to meet region-specific needs to tractors and farm equipment tailored to meet diverse needs, such as small tractors that can be of use in small farms, to adaptation practices communicated through extension services.

Through this technology-enabled equalisation in opportunities and technological options even when it was not scale neutral. In other words, the malleability of technology and methods in adaptation can result in the equalisation of opportunities. Hence it can be argued that cutting across classes of farmers Green Revolution was a tide that lifted all boats and at least ensured that there was a minimum gain/benefit irrespective of the categories of farmer. But whether such gains/benefits could be maximised or not depended on many factors, including the capacity to learn or adapt and the availability of credit and farming related services. In a review of Green Revolution, Pingali (2012) writes:

> Despite relatively low adoption of improved varieties, people living in marginal environments benefitted from the GR through consumption and wage linkages, such as lower food prices. Farm employment and growth in the nonfarm rural economy provided labor benefits to the landless rural poor and those people living in marginal production environments. Multi-country case studies of rice environments in Asia show that labor migration to more productive environments resulted in wage equalisation and was one of the primary means of redistributing the gains of technological change from favorable to marginal areas. Similar results were found for wheat grown in high- and low-potential

environments in Pakistan. There is also a growing body of evidence of spillovers from the productive regions that benefit the more marginal environments. These spillovers involve not only technology transfer and capital investments but also the software of development, such as local institutions, property rights, and social capital.

While Pingali (2012) acknowledges the shortcomings and limitations of the Green Revolution, he outlines the lessons to be learnt and look forward. Like him many others have pointed out the need for more research on global public goods and more investment in agricultural R&D. However, these alone may not result in greater equalisation through technology unless equalisation is also considered as an objective or goal in technology development.

In the Indian context, the leveraging of soil testing technologies for reducing the carbon footprints of agriculture is an exemplary achievement. The National Productivity Council (NPC) and National Institute of Agriculture Extension Management (NIAEM), Hyderabad have assessed the last five years of implementation of soil health card scheme. In their survey, NIAEM contacted around 3000 farmers in 200 villages in 16 states and found that cultivation cost has gone down by 4 to 10 per cent and income has gone up by 30 to 40 per cent. The NPC covered 1700 farmers in 19 states and 76 districts. They confirmed the reduction in chemical fertilisers by 10 per cent and an increase in average income of INR 4500 per acre. Detailed studies are there on crop and region-specific variations, etc.

Another example of technology in the agriculture sector is evident through the National Crop Insurance Portal (NCIP), a web-based integrated IT platform for easy access and interface among all the stakeholders, which has also been launched. Direct Benefit Transfer has also been introduced by the government since April 2017 to help farmers receive claims directly in their bank accounts, under the Pradhan Mantri Jan Dhan Yojana (PM-JDY) and JAM Trinity programme. Under the Pradhan Mantri Fasal Beema Yojana (PMFBY), during 2016 and 2023, 56.80 crore farmer applications have been enrolled and over 23 crore farmer applicant received claims of about INR 1.55 lakh crore.

Within the health sector, under AYUSHMAN Bharat Scheme, health services delivery has improved considerably. The biggest beneficiaries of this scheme are the poor families for whom health services provisions are expensive. As of May 2024, the number of hospital admissions has reached more than 6 Crore. In addition, more than 34 crore Ayushman Cards have been issued and 29,980 hospitals have been empanelled.

Adaptation of technological interventions in the health sector has been increasing at a great pace in India. There are initiatives to introduce telemedicine, remote diagnostics, and digital health platforms to ensure healthcare access even in remote areas. Telemedicine and digital health services have empowered individuals, particularly the youth, with a range of capabilities that contribute to improved healthcare of the population. The Government of India has launched Ayushman Bharat Digital Mission (ABDM) to expand access to timely, affordable, and safe healthcare for all 1.4 billion citizens wherever they are and whenever they need it.

The ABDM is digitalising healthcare by creating a country-wide digital health ecosystem that will enable patients to store, access and consent to share their health records with doctors and health facilities of their choice. ABDM is also creating a national digital health infrastructure starting with the building of Health IDs (ABHA IDs), Unique Identifiers for doctors and health facilities, Personal Health Records, and telemedicine and e-pharmacy, among other components. This scheme attempts to improve healthcare delivery by harnessing digital technologies. India's Digital health infrastructure can open doors for developing countries to learn and collectively build a global interconnected health ecosystem, supporting the vision of Universal Health Coverage.

When the pandemic wreaked havoc on the socio-economic fabric and strained our already overburdened healthcare systems, digital-technology enabled health solutions such as surveillance applications (Aarogya Setu), vaccination platforms (Co-WIN), data monitoring dashboards, and remote clinical management, bridged the gap in healthcare delivery in the midst of a crisis. India could indigenously harnessed digital public goods (DPGs) such as Aarogya Setu, a contact tracing application and CoWIN which not only helped administer more than 2 billion vaccine doses in India efficiently in a period of 18 months, but was also used by other developing countries to spearhead their vaccination strategy. The private sector which was the frontrunner in the advent of health technology also garnered market traction as health professionals and citizens, both flocked to tele-health platforms to seek consultations. These examples are a testimony to the enormous potential of technology in improving healthcare and place the spotlight on the need for introducing these in providing quality services to the last mile (Sharma, 2023).

Growth of the Healthcare sector through digital technologies, such as artificial intelligence, VR/AR, 3D-printing, robotics or nanotechnology is continuously improving our quality of life. Not only that, technology in the medical field has a massive impact on nearly all processes and practices of healthcare. Accessibility here is a major issue. It is worth pointing out that to enhance equitable access, affordable innovations have to be developed even as technologies become mainstream and are at the cusp of wider adoption. India's innovation in CAR-T cell therapy brings treatment cost from INR 4 crore to INR 40 lakh and as Central Drugs Standard Control Organisation (CDSCO) approved it in October 2023, more patients will benefitting from it soon.[5]

An excellent example of technology as equaliser is vaccines. Vaccines fundamentally changed child health across the world saving millions of children from death and disability. More importantly it enabled longer life for them and played a key role in reducing infant mortality. According to Chan (2014):

> In 1974, fewer than 5 per cent of the world's children were protected by vaccines against six killer diseases. Today, that figure is 83 per cent, with some developing countries reaching 99 per cent immunisation coverage". She further observes: "Immunisation, which makes universal coverage imperative, is also a potent social equaliser. Even in very wealthy countries such as the United States, it offers equal protection to rich and

poor, privileged and marginalised, promoting equally good health outcomes for all. Immunisation is making a value-added contribution to child survival, as vaccines are distributed together with insecticide- treated bednets, deworming tablets, vitamin A supplements, and tools for growth monitoring.

Medicines can act as equalisers and access to medicines thus can enhance the equalising potential of medicines. In the case of health, medical technologies and procedures like cataract have dramatically altered the lives of millions of persons across the globe.

Although by now cataract surgery has become a common one, easily available and affordable, the model pioneered by Dr. Venakataswamy Naidu, his sister and brother through Arvind Eye Hospital showed that it can be customised for mass adoption without any loss in technical efficiency or efficacy. On the other hand, the innovation here is not in technology per se but in the way the operation process was organised and scaled up. Interestingly this model developed in Madurai was later adopted with changes in public health camps for eye.

In the case of medicines and medical devices, the equalising potential is constrained by access. However, access is limited by various factors including intellectual property rights. In fact, in recent decades the role of intellectual property rights as a constraint has been a matter of debate. However, a few countries like India and Brazil chose a different path to overcome this by focusing on generics.

Production of generics in mass volume was facilitated in India by technologies used to find alternative processes to develop and produce drugs. Generics produced largely through innovations in manufacturing processes played a key role in making medicines affordable and accessible not just in India but elsewhere as well. This helped avert a major AIDS crisis in Africa. Although many other policy interventions were made, the real technological breakthrough was the innovation in production processes used by the generics industry. It took less than two decades for the industry to emerge as the world's leading generics industry supplying to the USA and Europe.

The equalising potential of generics is phenomenal as generics revolutionised access to medicines, and millions of patients are benefitted. What was remarkable is that generics could make access to medicines affordable for all types of diseases and make a major contribution to public health. It was a game changer because enhanced access with affordability ensured that people could not only get cured but also live longer. Although generics per se were not produced for the first time in India, it was India that pioneered generics as an affordable solution globally. The key lesson from the story of generics is that technology can be an equalising force when other factors play a complementary role by providing scope for the potential to equalise to be harnessed and make it widely available. While generics are available widely and are relatively cheaper, Government of India made them more accessible and cheaper by launching Jan Aushadhi Kendras that sell only generics and across the country there are about 11,000 such Kendras (shops).

In the case of renewable sources of energy, it is the regulation and policy frameworks in Nordic countries and Germany that played a key role in incentivising innovation in wind and solar energy respectively. These examples show that in an enabling environment, when governments, private sector and other actors in the national innovation system collaborate and complement each other, both development and diffusion are accelerated. Although no single country can claim that its policies are solely responsible for the solar revolution, what worked was countries building on earlier innovations. According to Nemet (2019):

> Progress in PV depended on each country not starting a new but building on the efforts of precursor countries. This is where the national system of innovation perspective is most helpful to understanding the solar evolution. Each time a transition occurred, the new leader was able to absorb the extant knowledge, and then add its own distinct contribution.

From the above discussion, it follows that the equalising potential of a technology by becoming accessible or affordable is difficult to estimate in the initial stages per se, because technology advances globally even if policies are mostly national or have a specific focus.

As of July 2023, India's installed capacity in renewable energy has been 172 GW. In solar energy, India is a global leader. Rapid strides have been made in wind energy and small hydro. In bioenergy also much progress has been made. The renewable energy revolution in India is much more than a successful adoption of technology. It is a frontal assault on energy poverty which is a significant problem in rural areas. In fact, this revolution has leapfrogged riding back on the revolution in technology and the policies and regulations that facilitated rapid capacity building in solar cell production, wind energy and biomass, and incentivising renewable energy.

There are a number of policies that favour renewable energy in India and they have ensured that the equalising potential is well realised. According to Venkateswaran *et al* (2018):

> Government subsidies reduce the Set Price for beneficiaries by 76 per cent to INR 120 (approx. 1.80 USD). Affordability in addition to Rural Lighting Needs and Set Price influence individuals' purchasing decisions. Perceived benefits of solar lamps affect how people view the Set Price, resulting in a calculus of Cost-Benefit ratio. Users identified various benefits such as increased study hours for children in clean light, reduced exposure to pollution and reduced health or fire risks to children previously caused by kerosene lamps. Kerosene use reduced as households transitioned from kerosene wick lamps to solar. Beneficiaries noted increased household productivity from a wide range of uses for the lamps, including their use while cooking, lighting at dinner, and performing household chores, irrigating farms, or selling goods in the grocery shop or marketplace after dark. Households also reported the versatility and use of solar lamps for evening social gatherings, village level meetings, emergencies, using an outdoor toilet, and as protection from wild animals at night.

The Union Budget 2020 has laid a major emphasis on use of solar energy for farming under the ambitious Pradhan Mantri-Kisan Urja Suraksha evam Utthan (PM-KUSUM) scheme. Recently, in January 2024, Prime Minister Narendra Modi announced the Centre's plan to install rooftop solar on one crore households under the Pradhanmantri Surodaya Yojna. The scheme aims to provide electricity to low and middle-income individuals through solar rooftop installations, along with offering additional income for surplus electricity generation.

The above discussion highlights how India has been using technological revolutions to further AEI and in this it has used a mix of policies and strategies often in synergy. For example, digitisation built upon DPI and platformisation has resulted in significant positive impacts in sectors like health, financial sectors and in services sector. Promotion and support to generics and renewable energy technologies and their diffusion and adoption has helped in achieving accessibility, affordability as well as energy poverty.

As India continues to build upon these and launch many similar and new initiatives to widen Access, Equity and Inclusion for achieving equitable and inclusive development transformation, there are of great relevance for the Global South too, we discuss some of the way forward in the following final section.

Relevance for the Global South and the Way Forward

In view of the preceding discussion there are some key messages of critical importance of linkages between institutional innovations, technological innovations, and an equitable development transformation. Countries and societies that have ensured a closer linkage have been successful in their pursuit for leading a technology-led development transformation which is equitable as well as inclusive; whereas countries and societies that have not paid enough attention to this have failed in several different ways and have faced increasing inequitable development. Not only the cost of adoption of technology is high for them but they also end up with huge exclusions. Efforts in the form of Technology Facilitation Mechanism (TFM) of the Agenda 2030, Technology Bank and more recently the Global Pilot Programme on STI for SDGs Roadmaps (STI4SDGs) have been made at the international level, but they are yet to fructify in achieving the desired outcomes.

In the case of India, as discussed earlier in this paper, the role of government and public sector in bringing about the institutional as well as technological innovations with the objective of harnessing technology as an equalising agent, has been the most significant factor for leading a transformational development trajectory which is equitable and inclusive. This endeavour enabled an ecosystem, wherein private sector could easily latch on and take forward the scale and intensity of technological development, deployment and diffusion at much faster pace and at much wider level. All of this has made a huge impact and we could witness that in certain areas it has led the country leapfrog and thus placing itself in a position of successful catching-up.

Drawing from the Indian experience, there are some of the following suggestions as way forward which could be of relevance for the Global South in their pursuit of promoting an equitable and inclusive development transformation.

Leapfrogging

The wider and faster diffusion of advance digital technologies, supported by sound policy interventions and initiatives across various sectors have led the phenomenon of leapfrogging. Lee (2019) argued that "India took a detour via leapfrogging", while becoming one of the successful latecomer economies. This leapfrogging has been propelled largely by the influx of technologies. According to Lee (2019), leapfrogging entails the latecomer getting ahead of the forerunners by adopting new technologies ahead of them, thus 'leaping' over them. Thus, leapfrogging is highly likely to succeed when it is executed during a paradigm shift or during an exogenous moment of disruption, which are basically 'windows of opportunity', in terms of early Schumpeterians, such as Perez and Soete (1988). Lee and Malerba (2017) argued that "institutional/public policy window opened through public intervention in the industry or through drastic changes in institutional conditions, played a prominent role in several catch-up cases, such as in high-tech industries in Korea and Taiwan, telecommunications industry in China, and pharmaceutical and IT industries in India."

In the present times, in the case of India, such a paradigm shift or 'window of opportunity' could be the creation of Digital Public Infrastructure (DPI). In the area of agriculture, we talked about assimilation and absorption, which may be very much part of leapfrogging per se. This itself would be equalising or enhancing access through technologies. Recent examples also show that leapfrogging can also be an equaliser in sectors such as health and finance. Energy is another area where lowering the cost of adoption may also be part of leapfrogging with low carbon footprints. These are possible because the technology adoption and leapfrogging went hand in hand and the environment was enabling. However, the real challenge could lie in making leapfrogging as an equalising one, on which the wider Global South would have to work collectively for a better future, where no one is left behind. India's experience did show that leapfrogging can be an equalising one, if backed by right combinatorial innovation approach.

Digital Public Infrastructure and Digital Public Goods

As discussed, Digital Public Goods (DPG) and Digital Public Infrastructure (DPI) have emerged as major ideas and practices, particularly in addressing digital divide and in ensuring that digital technologies play a key role in enhancing access to goods and services and contribute in many other ways including enhancing livelihoods and empowering weaker sections, particularly women. In terms of theory and praxis India's contribution this area is exemplary and pioneering one. More than technological leapfrogging, it denotes a combination of deployment of technology and access by the masses with multiplier effects. By deploying DPI that stands on the two legs of platformisation and data democratisation, many objectives have been fulfilled. New technological solutions especially IT solutions are not only changing the governance landscape in India but also empowering the poor and the less advantaged in novel ways which has transformative impacts on their socio-economic conditions. DPI-based platformisation and democratization has played a key role in this achievement.

One essential feature of the India's approach particularly in DPI relevant for Global South is the middle path between over reliance on market forces and tighter control and over regulation by the state in deploying DPI and creating an enabling ecosystem. This is highly compatible with UN's Digital Compact philosophy and is antidote to digital exclusion and exclusion by market forces. India can play a key role in advancing the contribution of DPI and DPGs. Although countries have different regulatory regimes and approaches towards data governance and technology governance, India's experience and approach can be very relevant particularly in countries that are embarking on digital revolution. India has offered these digital advancements as open-source solutions for the world. The countries of the Global South may adopt and adapt these technological solutions in customised formats suiting their needs and requirements.

Nature of Emerging Technologies

With the high transformational potential the outcomes and imperatives of the infusion of new technologies are becoming increasingly difficult to predict. We can use equalising potential of technology for maximising the social good but how this is to be harnessed is a different issue. Often the potential is amplified or constrained by policies rather than by science/ technology per se. The challenge lies in making technology as more or better equaliser, right at the stage of its development. With the rise of Industrial Revolution 4.0, we observed intensive digitisation with the race to control data. What Piketty *et al* (2022) says in terms of global wealth inequalities that the poorest half of the global population barely owns any wealth at all, possessing just 2 per cent of the total, whereas, in contrast, the richest 10 per cent of the global population own 76 per cent of all wealth, may become a reality for that 10 per cent population is also controlling the power to use data. Through AI, cloud computing and IoT, one can control water and electricity supplies in cities to pace-makers and other controls of all various kinds. UNCTAD and other institutions/think-tanks have highlighted the linkages between potential inequalities and emerging technologies and by now there is substantial literature on this topic. But how to address that is a major challenge in theory and practice. More work on AEI and emerging technologies is needed and what can be learnt, and deployed from India's experiences and approaches can be explored.

Need for New Approach and New Data

The social scientists need to work towards enriching the AEI framework. In addition, more approaches have emerged which very well supplement the AEI framework such as Responsible Research and Innovation (RRI) and Scientific Social Responsibility (SSR) frameworks. Collectively, these frameworks can do the act of balancing the equity part of technology absorption and its access. RRI has emerged as a new policy framework for assessment of technology. It seeks to align technological innovation with broader societal goals and values. In recent times, the idea of Scientific Social Responsibility (SSR), has emerged as an additional tool where nature of innovation, affordability, frugality, appropriate relevance and open sourcing play an extremely important role in defining the various contours of this multi-layered instrument.

With the new approaches on engaging science for societal welfare, the need to examine inequality from a holistic perspective becomes all the more important. Accordingly, data on science and technology would have to go beyond outputs or even income or consumption expenditure-based indicators. This is also relevant for impact assessment and evaluation of STI programmes and institutions. The development of relevant indicators and data points which capture not only the outputs (such as patents, publications, number of researchers etc.) but also the outcomes in terms of achieving equitable and inclusive development transformation. AEI-based indicators must be considered as an intrinsic element in any such endeavour for defining and devising new set of relevant indicators, particularly in assessing impacts of emerging technologies. Institutions like CESS should take up this as a research focus and connect the wider development objectives, strategies and work plan in the backdrop of a new era that technology has unleashed.

Endnotes

1 https://www.unesco.org/en/articles/science-benefiting-society-role-right-science

2 According to NITI Aayog digital platforms in India, thriving as a result of the increasing use of smartphones, low cost of internet and other initiatives under the Digital India campaign, has been able to provide various digital platforms that comprise the gig economy, thus leading to many innovative solutions in different sectors (NITI, 2022).

3 https://www.un.org/sites/un2.un.org/files/our-common-agenda-policy-brief-gobal-digi-compact-en.pdf

4 Digital Public Infrastructure (DPI) (itu.int)

5 https://indianexpress.com/article/cities/mumbai/indigenous-car-t-cell-therapy-now-available-for-commercial-use-9147148/

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Annexure 1

Indicators for AEI Index

Access	Equity	Inclusion
-Access to clean fuels and technologies for cooking (% of population) -Access to electricity (% of population) -Account ownership at a financial institution or with a mobile-money-service provider (% of population ages 15+) -Mobile cellular subscriptions (per 100 people) -Individuals using the Internet (% of population) -Proportion of population with access to electricity (SDG 7.1.1) -Fertilizer consumption (% of fertilizer production) -Nurses and midwives (per 1,000 people)	-Maternal mortality ratio (per 100,000 live births) -Infant Mortality rate, (per 1,000 live births) -Mortality from CVD, cancer, diabetes or CRD between exact ages 30 and 70 (%) -Proportion of population living in households with access to basic services (SDG 1.4.1) -Universal health coverage (UHC) service coverage index [SDG 3.8.1] -Proportion of population with primary reliance on clean fuels and technology (SDG 7.1.2) -Cereal yield (kg per hectare)	-Access to clean fuels and technologies for cooking, rural (% of rural population) -Access to electricity, rural (% of rural population) -Account ownership at a financial institution or with a mobile-money-service provider, female (% of population ages 15+) -Account ownership at a financial institution or with a mobile-money-service provider, primary education or less (% of population ages 15+) -Account ownership at a financial institution or with a mobile-money-service provider, poorest 40% (% of population ages 15+) -Renewable energy share in the total final energy consumption (SDG 7.2.1)

Source: Authors' own compilation based on World Bank's WDI Data Bank and UN SDG Indicators Database.

Annexure 2

Principal Component Analysis (PCA)

In general, a PCA is used to transform a large set of correlated variables into a smaller set of uncorrelated variables, termed Principal Components that account for most of the variation in the original set of variables. So, a PCA transforms the original variables into a new set of variables that are (1) linear combinations of the original ones, (2) uncorrelated with each other, and (3) ordered according to the amount of variation in the original variables, which can be accounted for by the new variables.

In mathematical terms, a PCA involves the following steps:

1. standardization of variables X1, X2, etc. for the mean zero and unit variance
2. calculation of the correlation matrix R
3. determination of the eigen-values λ1, λ2, ..., and λp and the corresponding eigen-vectors a1, a2, ..., and ap through the solution of equation below, where "I" is the identity matrix:

$$|R-I\lambda|= 0$$

4. elimination of components that have little contribution to the variance of the original data set
5. application of matrices of eigenvectors as the factors in a linear combination of standardized variables for the composition of the principal components.

The first generated principal component (PC1) explains the higher proportion of the total variance from the original database, while the second captures the higher proportion of the total variance not represented by the first, etc.

For a database of k variables, for example, the maximum number of extracted components would be k, regardless of whether there is a high correlation among its variables, in which a much smaller number of components would be enough to represent the highest portion of the total variance from the original variables. Generally, only the main components that obtained an eigen-value greater than 0.7 are used.

PCA have many alternative uses among which assigning the weights while computing an index is one.

Steps for Computing Index using PCA include:

- Collection of data on relevant variables
- Normalization of variables based on the association with the objective of grouping
- Assignment of weights using PCA

$$W_i = \Sigma \left| L_{ij} \right| E_j$$

where,

Wi is the weight of ith indicator

Ej is the eigen value of the jth factor

Lij is the loading value of the ith unit of grouping on jth factor

i = 1,2,3,…..n indicators

j = 1,2, Factors or Principal Components

- Index formation:

$$I = \frac{\sum X_i W_i}{\sum W_i}$$

where,

I is the index of each unit

Xi is the normalized value of ith indicator

Wi is the weight of ith indicator

After getting the raw Index data for all, the following formula is used to normalise the score (get the range between 0-100):

$$x' = \frac{x - min(x)}{max(x) - min(x)} \times 100$$

Where, x = raw data value
min(x) = minimum observed value of the indicator in the dataset
max(x) = maximum observed value of the indicator in the dataset
x' = normalised score after rescaling

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