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SDG Gaps and Technology Needs in Developing Countries: Scope for Locally Agile Technology Ecosystems

Sabyasachi Saha*

Abstract: The systemic approach to innovation at the national and regional levels is premised on several self-selection possibilities, in most cases driven by externalities. This necessarily contributes to inequalities among countries and disparities between regions with only a handful of regions emerging as innovation and knowledge hubs. Moreover, in developing countries, the roles of STI institutions and the private sector have rarely been complementary. Given huge information asymmetries and highly dynamic frontiers in the technology space, policy frameworks that are meant for national-level coordination are grossly inadequate, even as national agencies remain key players in resource mobilization. Such concerns are also ignored in the new literature on grand challenges and the need for systems transformations. Against this backdrop, we suggest a new policy framing viz. locally agile technology ecosystems (LocATE) that connects and prepares stakeholders for innovation and technology adoption at the sub-national level cognizant of divergent contexts and capacity gaps. The key priority is to make delivery on science, technology and innovation (STI) feasible to address immediate needs in terms of development, and build social and economic resilience over the longer-term (SDGs). The key pillars of the framework are: policy levers, anchor institutions, human resource strategies and capacity building, infrastructure, data preparedness, and participation of private sector.

JEL: O1, O330, O430

Keywords: Developing Countries, Innovation System, Technological Change, Technology Adoption, Technology and Welfare, Institutions, Sustainable Development Goals

Introduction

The technology question for sustainable development has far-reaching implications. Several existing technologies have not reached the last mile. Universal achievement of the Sustainable Development Goals (SDGs) would crucially depend on making technologies available across goals

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in developing countries with a specific sub-national focus. The gap between producers and users of technology has widened due to market and governance failures contributing further to regional disparities in developing countries. To correct such anomalies, collective efforts to forge new knowledge partnerships that facilitate knowledge creation and its use have been advocated as part of new models. In recent years faced with 'Grand Challenges', researchers have also started to define transformative policies that have some attention to altering technology ownership and flows. We note, with fast-moving technology frontiers, it would be pertinent to evolve strategies to take existing technologies to those who have not benefited from their presence and, at the same time, adopt new technology practices that embed access, equity and inclusion as fair norms for new technology enterprise. Policymakers and implementation agencies at various levels, including at the level of country, provinces, districts, cities, and rural areas etc., await a meaningful framework of innovation policy or ecosystem approach that takes care of their resource and capacity gaps and yet makes delivery on STI feasible to address immediate needs in terms of development, and help them build social and economic resilience over the longer term.

For obvious reasons, developing countries should have an adequate stake in the process to co-create and co-facilitate such processes. With rising demands of sustainability and equity in the creation and use of new emerging technologies, complementary frameworks alongside traditional innovation system approaches are being discussed to address disruptions in business models and changes in social behaviour (Schot and Steinmeuller, 2018, Geels *et al.*, 2008). For illustration, it may be noted that radical shifts in transport systems, energy systems, and food systems would be necessary to address environmental challenges. Such changes would only come through changes in technology profiles, introducing new business models and supportive policy and cultural systems (Geels *et al.*, 2008; Geels and Schot, 2007; DiMaggio and Powell, 1983). Innovation systems appropriated by countries to various degrees have traditionally addressed productivity and efficiency issues but need to increasingly cater to sustainability issues and minimize trade-offs between economic

growth, inequalities and sustainable development (Jacobsson *et al.,* 2004; Geels, 2005; Hekkert *et al.,* 2007). UNCTAD (2021) suggests that despite the fact that innovation systems are located and more mature in advanced settings, all countries and regions should be able to leverage technology and prepare for technological disruptions keeping in view demography, society, culture and ecology. Institutions, both in the public and private sectors, need to access information on technological opportunities, and individuals need access to information and tools to overcome locational disadvantages in most cases.

Box 1: State of the SDGs

The G20 New Delhi Leaders' Declaration acknowledges, "At the midway point to 2030, the global progress on SDGs is off-track with only 12 per cent of the targets on track" Despite the efforts in recent years, SDG gaps have widened across the globe and more particularly in developing countries which has brought back the focus on social sector goals. The Progress towards the Sustainable Development Goals: Towards a Rescue Plan for People and Planet Report of the UN Secretary-General (Special Edition) 2023 states that out of the 140 SDG targets, 30 per cent of the targets have shown no improvements or are regressed below the 2015 baseline. Going by the current trends, 575 million people will continue to live under extreme poverty, 84 million children will still be out of school, and close to 2 billion people will still not have access to clean cooking fuel and technology by 2030 (UNSG, 2023). The regional disparity is striking and indicates the unequal access to resources and technologies globally. It also states that in terms of hunger, the world had 150 million more food insecure people in 2021 than in 2019 with the majority of the setbacks seen in Sub-Saharan Africa, Central and Southern Asia region. For SDG 3, targets on child mortality Sub-Saharan Africa remains the region with the highest under-5 mortality rate in the world at 74 deaths per 1,000 live births in 2020. This is 14 times higher than the risk for children in Europe and Northern America. Under SDG 6 Eight, out of ten people who lack even basic drinking water service, live in rural areas, and about half of them live in LDCs.

Source: United Nation Secretary General Report on Progress of SDGs 2023.
G20 New Delhi Leader's Declaration.

In this paper, we try to address how developing country policymakers can be more sensitive to such issues. In light of the above, the demands of policy shifts have been huge, and policymakers and commentators are developing new-age policy practices on innovation, as captured in Section II. India's experience is taken as an example where sub-national innovation connect is still weak despite strong and successful policy push at the national level on leveraging technology for equitable development solutions (Section III). The significant disconnect between innovation capacities and development needs, further accentuated by regional disparities in terms of STI resources and capabilities, would come in the way of development transformations in response to emerging challenges. Lagging regions and sub-national jurisdictions suffer operational challenges of technology generation, adoption and absorption in the absence of a conceptual clarity and formalisation to aid policymaking. With a disproportionate population burden in the global south and higher shares in resource-poor regions, innovation enterprise has to go beyond the traditional ecosystem approach that seems to work only for 'well-endowed' regions. Hence, a new conceptual framework in the form of LocATE (locally agile technology ecosystem) has been proposed and discussed in Section IV followed by a way forward in Section V.

II. The Challenges of Framing Innovation Policy for SDGs

Over the years, the innovation system literature has gained attention and acceptance within a larger community of policymakers beyond science policy, and innovation systems are often referred to as aspirational policy paradigms that can resolve innovation bottlenecks (Freeman, 1987; OECD, 1997; Metcalfe, 1995; Asheim and Gertler, 2009). However, there is mixed evidence to this effect. The systemic approach to innovation at the regional level is premised on several self-selection possibilities (for research organisations, universities, enterprises and skills), in some cases driven by externalities. This necessarily contributes to inequalities among countries and disparities between regions, with a few regions emerging as innovation and knowledge hubs. Dhar and Saha (2014) articulated how

developing countries like India invested in their S&T infrastructure with key 'national' objectives over a long period of time but were still unable to address the immediate needs of the local industry or the development needs of the poorer populations. The SDGs and global challenges have created enormous difficulties for pre-existing S&T systems to reform and transform within a shorter time period in many countries, to take up new scientific challenges of direct relevance to the society already getting impacted by the unfolding of technological shifts, deepening crisis for example in one-health management and widespread dangers of climate change. The two-pronged challenge for STI ecosystems appears to indicate grand challenges further exacerbated by the absence of locally relevant innovation and technology institutions, skills, networks etc.

Iizuka and Hane (2021) suggest that SDGs depend on creative ecosystems and complementary assets. In their assessment, they bring out the preeminent stake of citizens in policy-making on STI. The role of governments is significant from the perspective of strategising on the commercialisation of appropriate technologies apart from technology choices. There have been attempts to explore possibilities of a new approach that builds on the framework of broader environmental and societal challenges, such as climate change, ageing societies, environment degradation, public health, energy, and mobility (Haddad *et al.*, 2022; Schot and Steinmueller, 2018). The private sector-led innovation enterprise which is the source of an overwhelming range of technological solutions, has most often responded to price signals. However, scholars are of the opinion that the transformational policy agenda for SDGs 2030 & beyond needs to focus on socio-technical changes and should not be driven by market forces or macroeconomics (Steward, 2012; Haddad *et al.*, 2022).

In recent times, we have encountered a new wave of innovation policy literature that brings in fresh perspectives to address unfolding complexities and mainstream sustainability transitions (Weber and Rohracher, 2012). The issue of sustainability transitions has been

accounted for in the so-called third-generation innovation policies. Encouragingly, this set of policies is more likely to focus on broader challenges rather than specific ones from a mission-oriented perspective (Mazzucato, 2016, 2018; Mazzucato *et al.*, 2020). The mission approach, however, relates to a new role for the government to manage complex technical challenges by eliciting partnership and cooperation from numerous stakeholders as part of the design (Schot and Steinmueller, 2018, Haddad *et al.*, 2022). In several aspects, third-generation innovation policies differ in their focus, perhaps away from economic growth or competitiveness (Haddad *et al.*, 2022).

The framework of STI ecosystems has taken an interesting turn where we see higher activity on the part of policymakers in experimenting with policy choices that have so far been less conventional. There is a greater emphasis on new frames focused on existing environmental and social challenges to guide STI policy in transition. In light of this, the mission-oriented policy literature and STI are both transitioning to a new frame focused on larger environmental and social issues (Haddad *et al.*, 2022). The general initiatives on market failure and innovation system policy choices have looked at firm-level innovation capacities, increased R&D investments and fostering collaborations without themselves emerging as potential developmental tools. Such policies have been intended to strengthen overall STI infrastructure and capacities to overcome market failure challenges, particularly in developing countries, those that have added to the competitiveness of firms through incentives for innovations, supply of STI workforce and pursuance of supportive basic research in publicly funded systems in developed countries. Building upon the rationale of market failure as originally proposed by Arrow (1962) and that of systemic failure developed by Woolthius *et al* (2005), Weber *et al.* (2012) introduced the transformational system failures argument to incorporate not only innovation performance but also transformative change that are strategic in nature. In Table 1, we outline the key failures of the transformative innovation system as identified by Weber *et al.* (2012).

Table 1: Outlining key Failures of transformative innovation system

Identified Failures	Types of Failures
Market Failure	• Information asymmetries • Knowledge spill-over • Externalisation of costs • Over-exploitation of commons
Structural system failures	• Infrastructural failure • Institutional failures • Interaction or network failure • Capabilities fail
Transformational system failures	• Directionality failure • Demand articulation failure • Policy coordination failure • Reflexivity failure

Source: Weber *et al.,* (2012).

Further, Haddad *et. al.* (2022) identifies second order challenges for transformative innovation policy in the form of the following:

- broadening perspectives on innovation policy;
- translating societal goals into concrete policy targets and practices;
- coordinating across policy domains and levels;
- characterising and attributing policy effects;
- empowering a broad set of stakeholders;
- balancing influence from incumbent actors;
- managing power struggles and conflicts of interest;
- navigating past policy dependencies; and
- developing institutional and governance capacity.

Further, globally there are new efforts to highlight the need for systems transformations and adequate support for transition efforts to address dual challenges of sustainability and human wellbeing.

Innovation policy space is also being evaluated from that perspective. A new strand of literature on transition policy and innovation linkages has emerged (Foxon and Pearson, 2008; Alkemade *et al.*, 2011). The spontaneity of sustainable technologies and their access would strengthen transition policies in all countries and influence evolution pathways for socio-technical systems. It is suggested that there is a need to harmonise the sustainability objectives of transition policies with that of economic growth perspectives of innovation policies.[1] While there could be displacement costs and resistance to transitions, policymakers stand to gain from more holistic knowledge of socio-technical dynamics at work, connecting multiple stakeholders and emphasising on coevolution (Kern and Smith, 2008; Geels, 2006; Schot and Steinmueller, 2018; Haddad *et al.*, 2022).

In terms of practical examples, the EU's Smart Specialisation strategy has economic objectives and was conceptualised as an economic framework of skill development and industrialisation. The local and urgent development needs, as is more evident in countries outside high-income ones, are not readily addressed under such frameworks, though they have more policy level acceptance in HICs or UMICs (even when not industrially advanced and are import dependent for technology). While the dichotomy between the primary, secondary and tertiary sectors is fast disappearing with deepening interdependence and convergence of underlying technology drivers, often such policy frameworks tend to have an industry bias, with local lobbying playing some role. Similarly, Japan's Society 5.0 has a strong ICT bias. However, developing countries may be in need of an array of non-ICT technologies as well.

Building on the variety of perspectives discussed in the literature with respect to new frames of innovation policy, we contend that SDG targets are universal in spirit but have local-level implementation mandates to harness convergence, enable monitoring and leverage partnerships. The SDG targets technically connect interrelated SDGs, ensuring co-benefits. Underlying the targets are specific indicators. Understanding of scientific challenges connected to development gaps

is well documented in many cases. However, a unified perspective in development policymaking on mapping specific development challenges with that of technological solutions is not available as part of the toolkit. The SDG indicators currently being used by countries, principally within the broader parameters originally set by the UN Statistical Commission, in spirit, aid in meeting the specific SDG target. However, due to data and methodology limitations, indicators are not sufficient for addressing the goals wherein convergence through policy design would prove to be innovations in themselves. This should be followed up with STI policy efforts on delivering specific developmental interventions.

Focus may be on those SDG indicators that are directly aligned with known and significant scientific challenges that arise out of pre-existing and complex development gaps and are not addressed by accessible technological solutions in developing countries. In mobilising efforts for STI for SDGs, therefore, access, equity, affordability alongside sustainability would be important considerations for any scientific enterprise. One way to encourage national planners and policymakers to pay attention to STIs for SDGs is by demonstrating that the use/availability of existing or potential STI solutions would help accelerate the achievements under respective indicators. From the perspective of developing countries, the diffusion of available technologies in all regions is equally important. With respect to grand challenges, developing countries are at a continued disadvantage and may not be in a position to develop, acquire or access STI solutions unless appropriate policy interventions are made.

Therefore, for 'STI for SDGs' to emerge as a framework for action, there is a need for greater collaboration and partnership among the actors. This is different from forging innovation ecosystems or encouraging peer learning to internalise multiple spillover effects. It is noticed that policies based on the understanding of innovation ecosystems bring in value addition in terms of directing science towards application domains. In such cases, public research laboratories and similar actors come in close contact with firms, both small and big, to work out prototypes or co-create

knowledge. This is perhaps an ideal scenario for a functional innovation ecosystem national, regional or sectoral. The push for innovations comes from natural progression in scientific research or commercial needs. However, there is less room to logically connect STI efforts with local development priorities across SDGs in most cases.

In developing countries, STI institutions and the role of the private sector have rarely been complementary. Saha (2015) analyses the criticality of quality parameters of publicly funded R&D directly influencing the spontaneity of the industry interface in India. The nature of the industry interface, to some extent, may be guided by policy, but ad-hoc policy choices on industry interface, intellectual property protection or knowledge sharing lead to sub-optimum outcomes. However, for the larger constituency of developing countries, it could be even more difficult to build capacities to the extent necessary for triggering a virtuous innovation cycle, despite examples where some emerging economies have been able to leapfrog in technology development and applications, saving both time and resources.

The challenge, however, is the iniquitous distribution of technology resources and the failure of developed countries to actually contribute to indigenous STI capacities in developing countries, more so because of historical colonial dependency in many cases. Over time developing countries that came to be characterised as emerging economies could make some progress in installing STI infrastructure or energising skill development in science and engineering. Practiced sporadically, the modality of capacity building, knowledge transfer or specific grants or concessional financing as part of South-South Cooperation has been beneficial in many cases in indigenous capacity building in S&T (Saha, 2018).

Finally, key elements of STI for SDGs Roadmaps have been presented in the UN Guidebook on STI for SDGs Roadmaps. However, the focus is primarily on a top-down methodology at the national level. Empowering local agencies and making provincial governments equally equipped is extremely important for STI for SDGs roadmaps, given the strong localisation principle embedded in the implementation of

the SDGs. This calls for an altogether new framing in the STI policy literature, which has so far tended to avoid difficult implementation challenges and underreported the importance of myriad local agencies with heterogeneous levels of preparedness across regions.

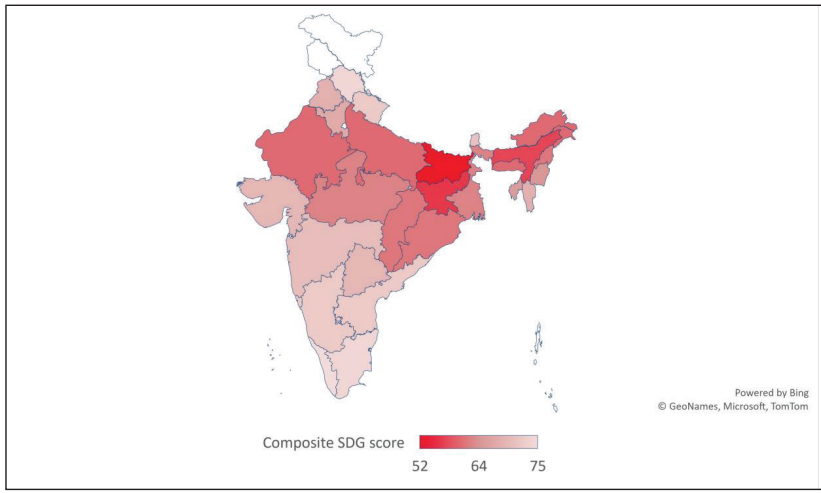
While conceptualising the utility of science and technology for citizen's welfare, the broader definition of innovation would, of course, be a useful starting point. However, given the structural deficiencies at the local level in most developing countries, the conceptual framework for innovation may not be fully comprehensible to policymakers or functionaries. In fact, it is more the actual use of technology rather than innovation that matters to them. Nevertheless, the roadmap on innovation is equally important because of the rapid pace of technological change and emerging possibilities of co-creation of knowledge and their stake in the solutions that are directly relevant to the local context.

III. SDG Gaps and Technology Needs in Developing Countries: Case of India

Regional Variation in SDGs and STI Capacities

NITI Aayog, which is the apex think-tank of the Government of India, has been computing the SDG India Index, since 2018, ranking Indian states on SDGs performance. The first SDG India index in 2018 was calculated based on the 62 indicators from 39 targets across 13 SDGs. The latest SDG India index (3.0) 2021 is computed using 115 indicators with over 70 targets from 16 SDGs. However, a few of the indicators were modified due to data non-availability. The data from the Indian states highlights significant disparities. The overall SDG scores of Chhattisgarh (61), Madhya Pradesh (62), Uttar Pradesh (60), Odisha (61), Jharkhand (56), and Bihar (52) are lower than the all-India average of 66. Refer to Figure 1 for understanding regional variation in overall SDG index scores for India. The state level performance differs widely across individual SDGs as well. For example, the SDG 2 (Zero hunger) scores of Bihar and Jharkhand stood at 19 and 31, respectively, much below the all-India score of 41, while that of Kerala and Tamil Nadu stood at 80 and 66, respectively.

Figure 1: SDG India Index



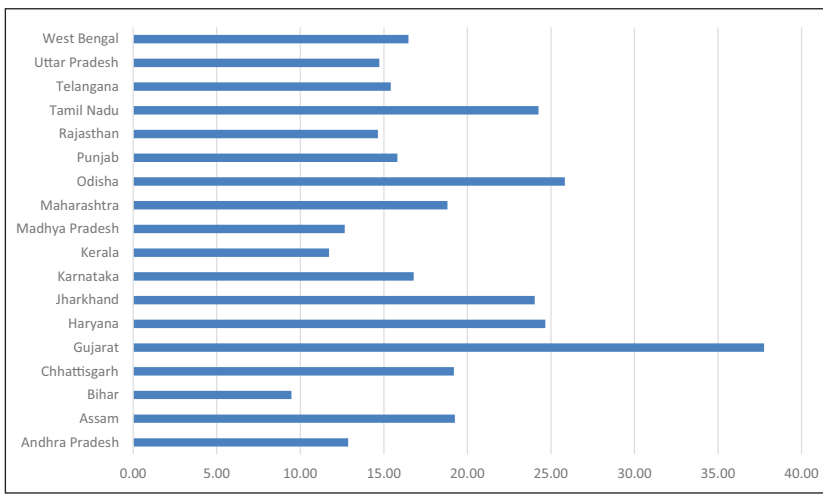
Source: SDG India Index, NITI Aayog, 2021.

Note: Only Indian States SDG composite score is depicted in the Figure.

We specifically focus on state-level performance on SDG 8 (Decent Work and Economic Growth) and SDG 9 (Industry, Innovation and Infrastructure). Progress mapped under SDG 8 is based on nine indicators that include the Annual growth rate of GDP (constant prices) per capita; Ease of Doing Business (EODB) Score (feedback score); Unemployment rate (%) (15-59 years); Labour Force Participation Rate (LFPR) (%) (15-59 years); Percentage of regular wage/salaried employees in non-agriculture sector without any social security benefit; Percentage of households covered with a bank account under PMJDY against target; Number of functioning branches of commercial banks per 1,00,000 population; Automated Teller Machines (ATMs) per 1,00,000 population; Percentage of women account holders in PMJDY. Among the large states Telangana, Tamil Nadu, Andhra Pradesh, Karnataka, Chhattisgarh, Gujarat, Kerala, and Maharashtra scored above the national score of 61. Madhya Pradesh, Haryana, Punjab, Rajasthan, West Bengal, Jharkhand, Uttar Pradesh, Assam, Bihar, and Odisha index scores were below the national score. Odisha scored the lowest amongst the large states with an index score equivalent to 48 points.

Similarly, the reports calculate SDG 9 score based on seven indicators namely; Percentage of targeted habitations connected by all-weather roads under the Pradhan Mantri Gram Sadak Yojana (PMGSY); Score as per Logistics Ease Across Different States (LEADS) report; Percentage Share of GVA in manufacturing to total GVA (current prices); Manufacturing employment as a percentage of total employment; Innovation score as per the India Innovation Index; Number of mobile connections per 100 persons (mobile tele density); and Number of internet subscribers per 100 population. Among the large states, Gujarat has scored the highest, followed by Tamil Nadu, Punjab, Haryana, and Maharashtra. However, several large states are still found lacking and behind in catching up, among them Bihar 'scores the lowest with an index score of 24. It is significantly lower than the national index score of 55. To add to the understanding, for illustration, we present State wise variation in gross state value added in manufacturing as a percentage of state GVA in the following Figure 2, which is self-explanatory.

Figure 2: Gross State Value Added by Manufacturing as a per cent of state GVA (at constant prices) (2021-22)



Source: Ministry of Statistics and Programme Implementation (MoSPI).

Note: States with population of more than 30 million are listed.

We also try to assess the wider context of STI capabilities across Indian states. However, data on State-level STI indicators are not compiled regularly and not much attention has been paid to deploy customised policy levers to address the gaps. We use the 2023 survey based report- The Assessment of Firm-Level Innovation in Indian Manufacturing conducted by the Department of Science and Technology (DST) to draw insights in this regard. This survey has captured some unique variables that give us a closer picture of S&T capabilities and propensities to engage in innovation activities. In the absence of more robust datasets, indicators for the manufacturing sector are used to understand the broader STI dimensions as discussed. The State level variations are compared on two counts i) availability of skills/ knowledge workers and ii) external orientation of firms. We have chosen 18 States out of 36 States and union territories of India based on population size being larger than 30 million.[2] As reported, stratified random sampling across state, sector and firm sizes was done to survey a sample of 10,139 firms covering 28 states and 6 UTs. The report defines innovation as a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process). Business innovation activities include all developmental, financial, and commercial activities undertaken by a firm that is intended to result in innovation for the firm. They include Research and experimental development (R&D) activities; engineering, design, and other creative work activities; marketing and brand equity activities; intellectual property (IP) related activities; Employee training activities; software development and database activities; activities related to the acquisition or lease of tangible assets; innovation management activities. Innovation activities can result in an innovation, be ongoing, postponed or abandoned.

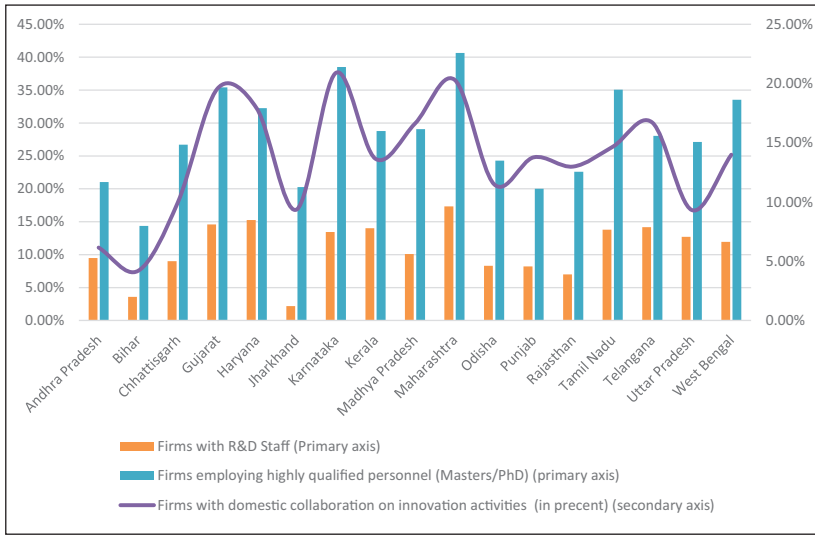
Table 2: State Wise Availability of Knowledge Workers/ Technical Staff and External Orientation of Firms in India – Insights from Firm Level Innovation Survey

(In percentage)

State	Firms with R&D Staff (1)	Firms employing highly qualified personnel (Masters/PhD (2)	Firms with domestic collaboration on innovation activities (3)	Firms with foreign collaboration on innovation activities (4)
Andhra Pradesh	9.49	21.03	6.15	1.28
Bihar	3.59	14.37	4.19	0.00
Chhattisgarh	9.01	26.71	9.94	0.62
Gujarat	14.60	35.40	19.55	5.45
Haryana	15.25	32.26	17.89	6.74
Jharkhand	2.18	20.25	9.35	1.25
Karnataka	13.43	38.51	20.90	5.67
Kerala	14.02	28.78	13.65	2.95
Madhya Pradesh	10.09	29.08	16.62	5.34
Maharashtra	17.32	40.65	20.32	5.77
Odisha	8.31	24.28	11.50	1.28
Punjab	8.20	20.00	13.77	2.30
Rajasthan	7.01	22.60	12.99	3.38
Tamil Nadu	13.79	35.06	14.66	5.17
Telangana	14.16	28.05	16.71	5.67
Uttar Pradesh	12.71	27.12	9.32	3.67
West Bengal	11.95	33.53	13.99	2.92

Source: Assessment of Firm-Level Innovation in Indian Manufacturing, Department of Science and Technology, Government of India, March 2023

Figure 3: Assessment of Firm-Level Innovation in Indian Manufacturing



Source: Assessment of Firm-Level Innovation in Indian Manufacturing, Department of Science and Technology, Government of India, March, 2023.

From the above Table 2 and Figure 3, we find prima facie alignment of indicators 1-3 for the firms that are based in the States that appear to be better endowed. We exercise caution here as the indicator values for both 1 and 2 are based on individuals actually employed, which implies that firms also draw employees from other states other than the one where they are located. This suggests that the availability of knowledge workers is also contingent on the attractiveness of the location and opportunities are not solely determined by local supply conditions. In that respect, the States that have a higher share of knowledge workers employed in the firms are also the ones that have better opportunities in terms of utilisation of skills. Another interesting observation is that firms are more oriented externally through collaborations for innovative activities in such cases. However, higher figures for domestic collaboration (3) in these states suggest formal interactions among firms within India and may be exploited for strengthening sectoral innovation systems in an institutionalised manner. We cannot, however, draw similar reference with

regard to foreign exposure or collaboration as shares are low even for well-endowed States. Delving deeper into this aspect can give important insights for India's innovation landscape.

Experience of Deploying STI for SDGs in India

India is creating a significant 'big' push through technology deployment through flagship welfare schemes for last-mile delivery. While a broad array of technologies is being delivered on the ground, the wider connection is coming from leveraging ICT technologies at a very large scale. This is also derived from India's push for Digital Public Infrastructure (DPI) that creates a mega universe of data-driven applications for government users, beneficiaries, citizens and other service providers.[3] The constant internal advocacy and capacity building within the government system to appreciate and leverage the power of digital technologies has created a natural self-sustaining momentum. Policy templates for large-scale social welfare programmes as well as social and physical infrastructure-driven efforts, are witnessing near universalisation of digital and emerging technologies like GIS tagging of assets, Hydro-Geo-Morphological (HGM) maps, IoT-based sensors, and other ICT applications. For illustration, we look at initiatives under four SDGs, also prioritised under the Indian pilot of the STI for SDGs Roadmaps (UN IATT, 2021). These are Food security and agriculture (SDG 2); health and wellbeing (SDG 3); access to water and sanitation (SDG 6); and access to clean and renewable energy (SDG 7). The push-through technologies have enabled progress of large proportion in addressing the challenges in these sectors.

Under the Public Distribution System (PDS), the One Nation One Ration Card scheme is now in operation and aims to ensure food security for migrant workers who were earlier excluded from the PDS umbrella. This scheme operates through two portals - Integrated Management of Public Distribution System (IM-PDS) and Annavitran (MoCAF&PD, 2021). Similarly, under the POSHAN Abhiyaan, the Poshan Tracker app is another important tool that provides daily data from 1.23 million Anganwadi centers.[4] It has around 100 million beneficiaries, including

pregnant women, lactating mothers, newborns, and adolescent girls. This app is a major source of real-time information for mapping nutritional status, vaccinations, and other maternal and child-related policy interventions (MoWCD, 2021). The Electronic - National Agriculture Market (e-NAM) is a virtual agricultural market that connects around 1000 Agricultural Produce Market Committees (APMC) in India. This market runs through a virtual e-NAM portal platform that provides real-time transactions and bidding data throughout APMCs (MoA&FW, 2022). ICT technologies are a major source of real-time information, monitoring and evaluation for these flagship schemes.

ICT tools and IoT sensors are being used under Mission Indradhanush to complement the Universal Immunisation Programme (UIP), targeting vaccination for approximately 27 million newborns and 29 million pregnant women annually. Under the mission, Electronic-Vaccine Intelligence Network (e-VIN), a technological ecosystem is developed that is used across 23,507 sites in 585 districts to get real-time information on vaccine stock inventory and storage temperature from every vaccine storage and cold chain point situated in peripheral government health facilities using cell phones, web-based applications, temperature loggers, and a cloud-based server (MoH&FW, 2018).

Similarly, Under the Jal Jeevan Mission (JJM), which aims to provide Functional Household Tap Connection (FHTC) to every rural household by 2024, the line ministry, in collaboration with other institutions, has developed an array of technological tools for delivery, monitoring and evaluation. A few innovative instruments deployed under the JJM are Hydro-Geo-Morphological (HGM) Maps developed in collaboration with the National Remote Sensing Centre (NRSC), Hyderabad, for locating groundwater sources - GIS technology for finding locations of existing water sources; village digital 3D contour maps prepared by Ministry of Electronics and Information Technology (MEITY) for the location of drinking water infrastructure; digital inventory of existing assets and overlaying them on GIS maps; Supervisory Control and Data Access (SCADA) system in Multi Village Scheme (MVS) for monitoring

treatment plants and distribution system; GIS technology and IoT based sensors to monitor the status of the functionality of assets and Solar Energy based stand-alone water supply systems for scattered/ isolated/ tribal/ hilly villages. Since the launch of the mission, around 100 million rural households have been provided with FHTC, bringing the total rural households with FHTC to 140 million out of the 190 million total rural households (MoJS, 2019, 2021, 2024).

However, challenges still exist in the deployment of technologies owing to the limitations of social and physical infrastructure. The experiences with India's flagship schemes have demonstrated the possible trajectories for countries in the Global South. Regional and social asymmetries in terms of natural, institutional and economic endowments have to be incorporated into policy-making to design technological tools in accordance with the adaptive nature of the regions and societies.

Table 3: Technology Platforms in Flagship Schemes

Flagship Scheme	Technology component
One Nation One Ration Card	Two portals - Integrated Management Public Distribution System (IMPDS) and Annavitran ePoS terminal with biometric scanner
e-NAM	e-NAM software hosted on Meghraj Cloud
POSHAN Abhiyaan 2.0	POSHAN Tracker Mobile application
Mission lndradhanush	Electronic Vaccine Intelligence Network (e-VIN)
Jal Jeevan Mission (JJM)	JJM Integrated Management Information System (IMIS) portal

Source: Authors' compilation.

IV. Covering STI Distance for SDGs through LocATE

In the literature, there is very little discussion on practical methods of overcoming challenges of technology availability through partnerships for innovation, more so from a South-South or Triangular Cooperation

perspective (Chaturvedi and Saha, 2021). STI for SDGs Roadmaps, which emerged from an international pilot project, could evolve into a powerful tool in this regard. However, it continues to focus on national frameworks only with sporadic attention in terms of strengthening regional or local institutions. Given huge information asymmetries in the technology space and highly dynamic frontiers, policy frameworks that are meant for national-level coordination are not sufficient from a developing country perspective, even as national governments remain key players in resource mobilisation. Against this backdrop, we suggest a new policy framing viz. locally agile technology ecosystems (LocATE) that connects and prepares stakeholders for innovation and technology adoption for fulfilling the mandate of STI for SDGs.

On the question of STI for SDGs, it can safely be said that key technologies are needed in the short to medium term as part of any template for development interventions in any region, irrespective of local capacities or resources. In fact, all development policy designs are increasingly being shaped by their technology content. From the perspective of the process involved, scientific discoveries and technological advancements need intermediaries to complete the feedback loop on assessing the nature of demand. Government agencies, national and sub-national, may play that role. But if private sector participation is weak, this process would again be incomplete. Here, the private sector involves local industry, SMEs, start-up ecosystems, healthcare facilities, etc. It is not always about introducing radical technologies but using fair improvements in scientific research that can be aligned with the most urgent local needs to fulfill the baseline indicators of the SDGs.

Interestingly, large developing countries, like India, have started to embark on comprehensive technology-oriented societal transformation to close long-standing development gaps. The bigger push on digital technologies has been more recent but is well stacked up with long run supply of ICT skills and a spontaneous explosion of open-source digital innovations. The key benefit of such a digital revolution in India is reflected in the jump in financial inclusion indicators with the

massive expansion of direct benefit transfers across categories of social benefits. Nevertheless, demand-side policies need further reorientation for innovations on STI for SDGs alongside industrial policies that are currently focused primarily on addressing long-term supply chain resilience in many countries. One important dimension with regard to STI for SDGs policies would be a roadmap on scaling up technology adoption (by local agencies and individuals), which is usually ignored in supply-side industrial policies.

For large countries, institutions have often been tagged national and regional. However, all institutions, in spirit, are regional in their embeddedness and have split responsibilities with national and regional objectives. In many cases, therefore, national systems of innovation and regional systems of innovation have been treated separately and attempts on leveraging the complementarities have been minimum. We also strongly feel that the role of non-STI institutions, particularly those that function as local governments and implementing agencies have remained on the periphery of such analysis even as they are key knowledge repositories on local level development needs as well as prime actors in implementation of development programmes of the federal and regional governments.

Further, as one of the main anchors of regional innovation systems, for example, universities in the US, Germany etc., undertake a lot of research catering to local needs. This dual role of institutions catering to national and region-specific needs has remained unresolved to a large extent, and hence, local agencies have been unable to tap the potential of universities and research organisations. In the Indian case, therefore, a major disconnect is observed with respect to regional needs, even though there is a robust university network spanning all regions. The research institutions and universities funded by the central government are usually better resourced than those funded through State budgets. The problem-solving at the local level and appropriate partnerships would be an effective solution for STI for SDGs. Increasingly, university research groups from high-income countries are taking an interest in

understanding specific problems in developing country societies. Hence, cross-country partnerships in research and applications also offer a significant opportunity under an STI for SDGs framework and could strengthen LocATE. This dimension has largely been ignored in regional systems of innovation or transformative innovation policy arguments.

The necessity to adopt a LocATE is eminently obvious because both national and regional systems of innovation seem to be of some relevance only if the institutions share similar objectives, are backed by resources and have longer memory of interactions. The idea of LocATE is to make technology adoption a reality with local ownership of processes for innovation, needs assessment, public service delivery, socio-economic assessment and confidence-building measures on the effectiveness of technology as a welfare tool. While we note the various kinds of "failures" and "challenges" identified in the literature, we attempt a policy frame that can resolve some of these key bottlenecks at the local level, particularly those related to information asymmetries, resource and capacity gaps involving high fixed costs, development policy challenges bridging national and regional needs aligned with SDGs (and convergence) and hence articulating the demand and direction; empowering broad segment of stakeholders among others.

Further, economically lagging regions need a different set of policies on development and sustainable transitions. International cooperation and partnership efforts have looked at capacity building and institutional strengthening either at the national level or with a narrow sectoral focus without paying attention to regional rebalancing. Regional specificity is key for the localisation of development. In this context, LocATE needs to emerge as an acceptable concept by bringing on board local industries catering to local needs, local food and agricultural systems, local transportation needs and maintaining the supply chain of primary commodities with priorities for decarbonisation and circularity. In this regard, we present an illustration of a workable model of LocATE in Table 4 capturing the various dimensions and modalities. The framework may have the following dimensions:

Table 4: LocATE – Suggested Policy Framework

A. Policy Levers	B. Anchor Institutions	C. Human resource strategies and capacity building	D. Infrastructure	E. Data Preparedness	F. Private Sector
• Introduce STI framework for SDGs in consultation with sub-national government/ local agencies • Assign work to specific agencies under anchor institutions (B) through proper selection criteria • Allocate finance for new institutional set up and capacity building • Leverage welfare schemes and other service delivery initiatives of the Government for effective local implementation	• Higher Education Institutions - Select Departments and research groups wherever appropriate • Research and Development Organisations (public and private) • NGOs, schools can act as supporting institutions • Coordinate introduction of pilot programmes in high priority areas for introducing technological solutions at the local level	• Select Faculty to join the efforts with additional incentives • Provision for sabbatical for both faculty and technical staff from public and private sectors • Appointment of other technical staff, special volunteers, apprentices • Capacity building, SOPs etc.	• Well-equipped yet cost effective facilities within existing institutions • High-speed Digital connectivity	• Statistical capacity for SDG gap analysis at the local level • Ability to undertake qualitative surveys and assessment of technological needs • Adoption of STI for SDGs Roadmaps tools • Capacity for impact assessment and socio-economic assessments	• Partnership with service providers in agriculture, health, water and sanitation, renewable energy etc. and promotion of local technology platforms including apps etc. • Leveraging social enterprises and impact investment through collaboration and partnership • Support local industries (including traditional industries) to develop customized low-cost technological solutions for SDGs • Scale up applications and promote diffusion of technological solutions

a. Policy Levers
b. Anchor Institutions
c. Human Resource Strategies and Capacity Building
d. Infrastructure
e. Data preparedness
f. Private sector participation

In the absence of a coherent approach from a 'system' perspective it would be difficult to energise local institutions – the ones dedicated to perform STI tasks (that may vary in degree and depth) as well as others that perform various administrative and governance roles in implementing various schemes and policies of the government. For many LMICs and LICs, such institutions at the local level are weak or nascent. This creates significant disparities in endowments. Efforts should be made that interaction between STI and non-STI institutions is encouraged with minimum deviation from their original mandates and in a manner that their roles become complementary. This mediated interaction requires institutional approaches drawing upon relatively stronger institutions in either space as appropriate, but with due consideration for the dimensions that have been highlighted here. Interestingly, each of these dimensions has its strong externalities and needs to be harnessed in tandem. However, depending on the context with relative strength of the dimensions adequate and appropriate response is needed. For example, in the Indian context, welfare schemes and other service delivery initiatives of the Government, alongside adequate focus on infrastructure development are emerging as strong entry points for effective local implementation. Localisation of development and innovation needs, however, would need strong support through local level policy choices, possible contributions from anchor institutions in the STI space, appropriate strategies on human resource mobilisation for long-term sustainability and innovation, data preparedness and effective partnership with the private sector enterprises (those incidentally may be beneficiary of government support but not connected with STI for SDGs needs).

V. Recommendations and Way Forward

The SDGs are facing multiple challenges across regions due to resource, technology and capacity gaps alongside regional imbalance prominent in developing countries. The SDG bottlenecks show a country's overall circumstances with regard to the welfare of its citizens. The urgency to facilitate more in terms of financial resources, knowledge assets and other enabling conditions is dependent on appropriate conceptual and policy frameworks guiding specific interventions. One such aspect is convergence, as put forth by the SDGs. But more needs to be done in implementing governance processes that address local data gaps on hard and soft infrastructure to mitigate regional imbalances within countries. Incorporating parameters under an STI for SDGs framework to assess technology needs at the local level is critically important. In most cases, technologies are largely implemented through national-level planning and policy with negligible participation of local agencies. While all regions are not expected to develop strong institutions in the short-to-medium term, a few steps may be taken as part of STI for SDGs Roadmaps implementation to generate more data on STI gaps for SDGs at the local level. This needs to be mapped with indicators for technology adoption and absorptive capacities.

Development and sustainability transitions are perhaps leading societies to deeper transformation. Existing inequalities are a result of the inability to course correct in the systemic sense. The climate challenge is a result of widening socio-economic inequalities and would cause poverty of means for many in developing countries. If economies search for equitable development and at the same time adopt 'lifestyles' for a sustainable future, the process of knowledge generation, production and utilisation needs to undergo paradigm shifts. No doubt, the innovation systems approach is also witnessing incremental shifts in policy even as technological disruptions are far more profound. For example, 'open-source' is no longer an alternate innovation paradigm but is very much mainstream. Similar shifts are necessary for skill generation and the ability of individuals and institutions to contribute to innovation.

The regional specificity, acknowledging long standing disparities, needs to guide several of these initiatives. Locational advantages and disadvantages should inform STI for SDGs policy enterprise as we see strong sustainability drivers taking centre stage.

The SDGs seek holistic outcomes in all regions as challenges are interconnected. Therefore, the SDGs should be able to guide innovation pursuits towards integrated and inclusive innovations with adequate stakes for local actors. The principal thesis of proposing a new approach to innovation systems is to acknowledge regional disparities, particularly in developing countries, and imperatives of creating suitable capacities and STI skills so that even the most advanced emerging technologies can be harnessed by enabling local production and absorption. Policy push by national governments and demonstration of willingness by sub-national agencies for creating such conditions of public-private partnership for development solutions, lifestyle shifts, participatory innovations, technological absorption and new skills would be critical for undertaking innovation policy for impact in developing regions. This could sum up to LocATE (locally agile technology ecosystems).

The unfolding technology revolution of recent years has compelled countries to look into its real benefits i.e. impact on the quality of lives of citizens in developing countries. International cooperation, even by developing countries, has tended towards bringing home new technologies, knowledge and capacities to initiate and accelerate development transitions and poverty alleviation, skill building and not mere widening of consumer choices or creating a stable supply of goods and services. The emerging modality of triangular cooperation involving technologically stronger emerging economies for delivering development cooperation in other LMICs and the LDCs is gaining greater traction among high-income countries. However, with pre-existing gaps and tight timelines for the SDGs, fuller realisation of technology-enabled development processes still remains a considerable challenge.

Endnotes

[1] In this way, third-generation innovation policy differs from prior generations, regardless of whether the earlier generation was growth-oriented STI policy or policy focused on completing narrowly specified goals (Haddad *et. al.*, 2022).

[2] Approximate state level population is calculated from State-wise Aadhaar Saturation Database which reports project State wise population for 2023 based on Registrar General of India data. Can be accessed from https://www.uidai.gov.in/images/StateWiseAge_AadhaarSat_Rep_31052023_Projected-2023-Working_sheet-Final.pdf.

[3] G20 Countries during India's Presidency in 2023 for the first time agreed to a common definition of Digital Public Infrastructure as "a set of shared digital systems that should be secure and interoperable, and can be built on open standards and specifications to deliver and provide equitable access to public and /or private services at societal scale and are governed by applicable legal frameworks and enabling rules to drive development, inclusion, innovation, trust,and competition and respect human rights and fundamental freedoms."

[4] Anganwadi Centre: Mother and child care centre in India.

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