Strengthening science, technology, and innovation-based incubators to help achieve Sustainable Development Goals: Lessons from India

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Abstract

Policymakers in developing countries increasingly see science, technology, and innovation (STI)-based entrepreneurship as an avenue for meeting sustainable development goals (SDGs). But market failures and underinvestment in societal goods by the private sector call for government interventions in supporting STI-based startups. Using the specific case of India, we examine whether and how publicly-funded incubators could contribute to implementing SDGs through STI-based entrepreneurship. We examine why incubators were created under different policy priorities between 1985 and 2014, what public agencies did to implement policy and what were the outcomes, and how some effective incubators were able to help address the developmental challenges that were formalized in the SDGs in 2015. We find that effective incubation for supporting STI-based entrepreneurship to meet developmental challenges extends beyond traditional incubation activities of providing support services, mentoring, networks, or infrastructures. Effective incubators actively build human capacity, muster public and private financing to support startups, and help incubatees better understand and connect to market and societal demands. Our analysis suggests that public policy could play an important role in strengthening existing and new incubators through training and support programs for incubator managers, facilitating demand creation, promoting coordination between multiple incubator programs that may already exist within a country, and incorporating targeted SDGs in specific incubator goals and activities. However, efforts to develop incubators to link STI and SDGs will yield limited results absent adequate parallel investments in capacity building for STI.

Keywords: Science technology and innovation; developing countries; entrepreneurship; incubators; public policy; sustainable development goals
1. Introduction

Policymakers and scholars—especially in developing countries—have long perceived that innovation and entrepreneurial activity can potentially generate new ways to advance economic development, employment, and more effective and efficient delivery of services (Acs et al., 2008; Audretsch et al., 2007; Naudé, 2010; OECD, 2013; Szirmai et al., 2011). A key focus of public policies for promoting entrepreneurship in developing countries has been on strengthening science, technology, and innovation (STI) and linking STI-activities to markets with the help of startup incubators—i.e., formally organized entities formed with governmental support that offer various services for the conversion of individual ideas from high-risk innovation and early-stage startup incubatees to more advanced, market-oriented enterprises. Countries like India, Brazil, and China have had long-running incubator programs that advance economic development while countries elsewhere, e.g. in Africa, have recently started to expand STI-based incubator activity ((Akçomak, 2009; Chandra and Fealey, 2009; Chandra and Silva, 2012; Dalmarco et al., 2018; Lalkaka, 2002; Scaramuzzi, 2002; Tang et al., 2013; The Economist, 2017).

Since the mid 2010s, STI and entrepreneurship are very much seen as an objective of, and a way to contribute to, the achievement of the Sustainable Development Goals (SDGs). While developing countries have had economic, social, and environmental objectives for several decades, the 2030 Agenda and the adoption of SDGs in 2015 formalized these goals globally and in that process, cemented the importance of STI and entrepreneurship in implementing the SDGs (UNFCCC, 2018). 

Goal 8: Decent work and economic growth target 8.3 mentions promoting “development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation…” (United Nations, 2015). Goal 9: Industries, innovation, and infrastructure specifically aims to enhance innovation and research and development activities in target 9.5 (United Nations, 2015). Similarly,
Goal 13: Climate action links to the Paris Agreement; the latter states that “Accelerating, encouraging and enabling innovation is critical for an effective, long-term global response to climate change and promoting economic growth and sustainable development” (UNFCCC, 2015; United Nations, 2015). This perspective on STI for SDGs is translating to an exploration of concrete actions on startup incubators and entrepreneurial activity that incubators can help promote to implement these goals.1

Given the renewed emphasis of incubators and startups in the context of SDGs, questions emerge for policymakers on how publicly-funded incubators in developing countries can most effectively link STI-based entrepreneurship with multiple SDGs.

Despite the significance of incubators in linking STI with SDGs, there is a gap in the understanding of incubators’ goals, activities, and their contributions to sustainable development outcomes in developing countries. Extant literature has extensively analyzed incubators and their impact on innovation and entrepreneurship largely in European countries, the United States, or other industrialized countries (Dutt et al., 2015; Kochenkova et al., 2016; Mian et al., 2016; Phan et al., 2005), noting that there is no single or consistent framework of assessment to measure success (Phan et al., 2005). In the context of developing countries, most studies analyze incubator activity under broader assessments of STI and entrepreneurship (Acs et al., 2008; Akçomak, 2009; Autio et al., 2014; Naude, 2013; Naudé, 2010) while only a few studies analyze what incubators have actually accomplished (Akçomak, 2009; Lalkaka, 2002; Tang et al., 2013). The distinction between incubators in industrialized

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1 For example, the Green Climate Fund (GCF), the financial arm of the UNFCCC is planning a program to support climate technology incubators and accelerators in developing countries. As part of this, the GCF, in partnership with the Technology Executive Committee (TEC) and the Climate Technology Centre and Network (CTCN) of the UNFCCC held a global dialogue in 2018 to advance climate technology incubators in developing countries (Green Climate Fund, 2018; UNFCCC, 2018)
and developing country contexts matters because of the following. Industrialized countries with greater resources, strong innovation systems, and strong institutions use incubators to meet policy goals of expanding private sector economic activity—publicly-funded incubators helped meet these goals by supporting high-risk startups (e.g., Leyden and Link, 2015). In contrast, in developing countries, incubators focus on achieving the social, environmental, and economic goals embodied in the SDGs that are unlikely to be met by the private sector. Multiple market and policy shortcomings—e.g., related to underdeveloped institutions, lack of human and financial resources, insufficient paying capacity by beneficiaries (Khanna and Palepu, 1997)—exacerbate the ability to develop new knowledge or to effectively translate it into application, leading to underinvestment by the private sector in innovation or in high-risk startups. At the same time, insufficient monetization of public goods (often central to the SDGs) further impedes private sector investment and activities in these areas. These contrasts in the role of incubators in industrialized and developing countries illustrate the need for context-specific analysis because the differences in why incubators were set up, their operational activities, and their goals will influence the metrics for success and the types of startups that incubators support and the outcomes they generate.

This paper addresses the research question: have STI-based incubators and the startups that they support historically helped to implement objectives related to SDGs in developing countries? We address this question from three perspectives. First, focusing on the policy drivers and development goals for STI-based entrepreneurship, we assess why incubators were created. Second, focusing on the public agencies responsible for designing and implementing government-led programs for supporting STI-based entrepreneurship, we analyze what these agencies did to implement policies using incubators
as intermediaries and what were the outcomes. Third, focusing on actual incubators, we analyze how incubators have been successful in the context of implementing sustainable development goals.

Our analysis on the potential relevance of incubators for implementing SDGs focuses on India. India is suitable for a case study because its incubator activities echo global trends—(a) from its historical multi-decade experience in governmental STI-based entrepreneurship programs that led to the creation of over 140 incubators between 1985-2014, to renewed policy emphasis since the mid 2010s that called for supporting startups by massively expanding the number of existing incubators (alongside improving other factors such as easing regulatory barriers, providing high-risk funding for startups, and increasing innovation capacity). But despite three decades of continued experiences linked to incubators and whether they met societal, environmental, or economic development goals, limited systematic analyses exist of one of the longest running governmental efforts to promote STI-based entrepreneurship in a major developing country (GIZ, 2012; Lalkaka, 2002; Tang et al., 2014). An analysis of India’s rich experiences can provide useful lessons for developing countries that have new and ambitious plans to mobilize STI-based entrepreneurship for implementing SDGs.

The rest of the paper is structured as follows. Section 2 provides a brief background on public policy for STI-based entrepreneurship and incubators. Section 3 focuses on the case context and our approach for the analysis of incubators in India. Section 4 discusses our results on the policy

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2 Author calculations
3 In 2014-2016, STI-based entrepreneurship became a specific policy priority and the government announced a set of ambitious national-level policies (e.g., Startup India, Atal Innovation Mission) and various regional-level initiatives for startups
motivations behind why incubators were created, what public agencies did to implement policy and what were the outcomes, and finally how incubators were able to implement SDGs. Section 5 highlights policy implications for incubators in developing countries. Section 6 concludes.

2. Background
In this section, we highlight the literature on STI-based entrepreneurship and startups in developing countries (2.1), how incubators broadly support STI-based entrepreneurship (2.2), and finally, the specific role incubators play in developing countries (2.3).

2.1. STI policy and startups in developing countries
The importance of innovation and entrepreneurship in pushing economic development has been long established, with clear recognition of science and technology as precursors to innovation (Freeman and Soete, 1997; Naudé, 2010; OECD, 2013; Schumpeter, 1934; Szirmai et al., 2011). Consequently, governments have focused on generating and supporting STI-related activities expecting economic welfare outcomes such as employment and industrial competitiveness. STI policy (in industrialized as well as developing countries) has emphasized on three areas. One, strengthening the ‘supply-side’ for STI—e.g., by promoting science and technology-based education, setting up research and development (R&D) laboratories, funding R&D in universities, creating science and technology-based large public enterprises, improving intellectual property rights (IPR). (e.g., Etzkowitz and Leydesdorff, 2014; Fagerberg et al., 2005; Nelson, 1993). Two, supporting entrepreneurship at large—e.g., by implementing policies and programs that finance small and medium business or startups, easing regulatory barriers to start or end a business. (e.g., Acs and Szerb, 2007; Minniti, 2008). Three (discussed in more detail in 2.2), strengthening the links between STI, entrepreneurs, startups, and markets—e.g., through setting up incubators (and other intermediaries like science parks, technology
transfer centers, etc.) that support technology transfer especially for technologies related to societal goods that would be unable to advance to market in the absence of different types of public support (e.g., Mian et al., 2016; Phan et al., 2005).

In the context of implementing SDGs, the link between STI and specific SDGs has become most apparent in the emergence of startups linked to the SDGs and the incubators that would support these (See Table 1). While startups have become attractive in industrialized and developing countries alike because of their perceived ability to be nimble and to quickly adapt to market needs (and therefore deliver quick results), STI-based startups for SDGs in developing countries face a unique set of challenges. First, STI-based startups are risky by definition and these risks are amplified by challenges that relate to SDGs, for example in the unavailability of infrastructures or human capacity needed for success (Autio et al., 2014; Ghani et al., 2014). Second, the success of STI-based startups depends in multiple ways on the private sector. But because of multiple market failures in developing countries, the private sector has undervalued the long-term societal benefits of implementing SDGs and underinvested in STI-based startups. These market failures include: (a) lack of resources to test or validate risky STI-based ideas, (b) paucity of early adopters willing to take up new technologies, (c) lack of long-term investment in STI-based startups (excluding IT-based startups) that clashes with the long timescales needed for STI-based startups to demonstrate outcomes (STI based startups may need more time to create or test prototypes, to manage supply chains and physical distribution of the product, and to demonstrate market acceptance), and (d) low monetary returns for public goods related to SDGs despite their high societal benefits (e.g., Khanna and Palepu, 1997). Overall, effective government-led activities that link STI-based startups with the implementation of SDGs would need to incorporate the unique context and challenges that such startups may face in developing countries.
and public and encouraging innovation and substantially increasing the number of research and development workers per 1 million people.

### Table 1: Examples of the links between STI, SDGs, and incubators from India and other developing countries

| Sustainable Development Goals | Description | Illustrative examples of the links between STI and SDGs from India and other developing countries |
|------------------------------|-------------|---------------------------------------------------------------------------------------------|
| 1   No poverty               | End poverty in all its forms everywhere                                                  | UNDP’s Big Data for Development Initiative runs a project on measuring multidimensional poverty using mobile data in Sudan (UNDP, 2018a). |
| 2   Zero hunger              | End hunger, achieve food security and improved nutrition and promote sustainable agriculture | Indigram Labs Foundation, an incubator in India, focuses on agriculture technology. Its incubatee startups include New Leaf Dynamic Technologies that is building off-grid cold storage units for farmers to help minimize post-harvest losses (Indigram Labs, 2018). |
| 3   Good health and well-being | Ensure healthy lives and promote well-being for all at all ages                          | MicroMek is a startup based in Malawi that aims to develop low-cost autonomous drones to deliver medicines and health care supplies to remote populations (Kaliati, 2019). |
| 4   Quality education        | Quality education                                                                        | Injini, a pan-African incubator, focuses on education technology. Its incubatee startups included M-Shule, a startup from Kenya, that aimed to develop an adaptive learning platform that could deliver personalized lessons through SMS (Injini, 2019). |
| 5   Gender equality          | Achieve gender equality and empower all women and girls                                   | Solar Sister is based in Sub-Saharan Africa and empowers women to become entrepreneurs by bringing clean energy into their communities through women-led enterprises (Solar Sister, 2019). |
| 6   Clean water and sanitation | Ensure access to water and sanitation for all                                            | India’s Department of Industrial Policy and Promotion (DIPP) organized a “Grand Challenge” competition for startups that link to the government-led mission of clean water and sanitation (Swachh Bharat Mission). One of the winning startups, Altersoft Innovations, is developing smart, self-cleaning public toilets using internet of things (IoT) technologies (DIPP, 2018). |
| 7   Affordable and clean energy | Ensure access to affordable, reliable, sustainable and modern energy                  | M-Kopa is a Kenya-based startup that sells solar home systems and allows buyers to make digital payments in a pay-as-you-go model (M-Kopa, 2019). |
| 8   Decent work and economic growth | Promote inclusive and sustainable economic growth, employment and decent work for all   | In Uttar Pradesh (the most populous state in India), the state Information Technology (IT) and Startup policy aims to use IT as a way of bringing in economic growth and has established four incubators as part of this effort (Government of Uttar Pradesh, 2017). |
| 9   Industry innovation and infrastructure | Build resilient infrastructure, promote sustainable industrialization and foster innovation5 | Supporter by India’s Biotechnology Industry Research Assistance Council (BIRAC), the Centre for Cellular and Molecular Platforms (C-CAMP) runs an incubator that focuses on supporting STI-based startups in the life sciences industry (C-CAMP, 2019). |
| 10  Reduced inequalities     | Reduce inequality within and among countries                                           | The Assistive Technology Accelerator (ATA) based in India supports startups and persons with disabilities. Its incubatee startups include Eye-D that is developing an app to help visually impaired with travel, identification of objects, and reading text (Assistive Technology Accelerator, 2019). |
| 11  Sustainable cities and communities | Make cities inclusive, safe, resilient and sustainable                                 | Mellowcabs is a South African startup that manufactures and operates solar-powered electric pedicabs and improves first and last mile public transportation in urban areas (Mellowcabs, 2019). |
| 12  Responsible consumption and production | Ensure sustainable consumption and production patterns                                  | Fly Catcher Technologies is an Indian startup that develops storage units to convert organic waste into biogas for household use (DIPP, 2018) (also part of the Swachh Bharat Grand Challenge, see SDG 6). |
| 13  Climate action            | Take urgent action to combat climate change and its impacts                            | The Global Cleantech Innovation Program led by the United Nations Industrial Development Organization (UNIDO) and the Global Environment Facility (GEF) aims to strengthen the entrepreneurial innovation ecosystem in developing countries. |

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4 Goal 8 has specific targets that explicitly link to STI. For example, Target 8.2 aims for “economic productivity through diversification, technological upgrading and innovation...”. Target 8.3 supports “…productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises...” (United Nations, 2015).

5 Goal 9 has specific targets that explicitly link to STI. For example, Target 9.5 aims to “enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending.” Target 9.B supports “domestic technology development, research and innovation in developing countries...” (United Nations, 2015).
and supports demand-driven small and medium enterprises and startups (UNIDO and GEF, 2018). The Green Climate Fund (GCF) is planning a program to support climate technology incubators and accelerators in developing countries (Green Climate Fund, 2018; UNFCCC, 2018).

|   | Life below water | Conserve and sustainably use the oceans, seas and marine resources | Evoware is an Indonesia-based startup that is developing edible seaweed-based packaging to replace plastic packaging that is a major contributor to marine pollution (New Plastics Economy, 2019) |
|---|------------------|------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 14 | Life on land     | Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss | Green Charcoal is a Uganda-based startup that replaces wood charcoal and firewood with agricultural waste (e.g. rice husk) (Green Charcoal Uganda, 2019). |
| 15 | Peace, justice and strong institutions | Promote just, peaceful and inclusive societies | UNDP Honduras developed a pilot ‘Fab Lab’ to 3D print hand prostheses for returning migrants and victims of violence who live with disabilities (UNDP, 2018a) |
| 16 | Partnerships for the goals | Revitalize the global partnership for sustainable development | The Climate Technology Center and Network (CTCN) of the UNFCCC consists of a worldwide network of organizations that support the development and transfer of climate technologies to developing countries (CTCN, 2016) |

The discourse on the types of government-led action needed for linking STI and SDGs has focused on setting up global, national, and subnational roadmaps that can help, among others, link STI policy with the 2030 Agenda and create enabling conditions to support a robust innovation system (IATT, 2018). Effective roadmaps need an evidence base that builds on specific experiences of developing countries in linking SDGs (and similar development goals) with policies for STI—in this aspect, as we show in the following sections 2.2 and 2.3, incubators have played a vital role.

### 2.2. Incubators for STI-based entrepreneurship

Incubators have been a vital element of STI policy (Aernoudt, 2004; Mian et al., 2016; Phan et al., 2005) in their role as intermediaries that link startups with networks of universities, investors, industry, government, etc. (Dutt et al., 2015; Peters et al., 2004). Incubators originated in the 1980s in the United States and have since been used worldwide (Akçomak, 2009; Allen and McCluskey, 1991). Estimates indicate nearly 7,000 incubator programs around the world of which a third focus on STI-based entrepreneurship (Mian et al., 2016). While various incubator configurations exist (such as accelerators and science parks), incubators are generally considered not-for-profit entities that receive varying levels of assistance from public funding bodies and provide long duration support for startups (up to
five years) to help the conversion of individual early stage, high-risk ideas to marketable enterprises (Cohen, 2013; Dee et al., 2011; Hackett and Dilts, 2004; Mian et al., 2016). Incubators traditionally offer support services to startups including infrastructure (working space and associated basic physical infrastructure, workshops), finance, business capability (mentoring, training, consulting), and access to networks (Amezcua et al., 2013; Cohen, 2013; Dee et al., 2011; Dutt et al., 2015; Hackett and Dilts, 2004). Overall, incubators play a vital role in strengthening the ecosystem in which startups operate.

A rich body of literature on incubators in industrialized countries has shown that incubators have diverse types of primary goals and operational activities related to their incubatee startups, and these result in different types of innovation-related outcomes. For example, incubator goals could vary in the focus on broad STI or on the development and transfer of specific technologies, in the emphasis on economic development and employment generation, or in the linkages to universities or private sector, while outcomes could be linked to product-, process- or organizational- innovation (Barbero et al., 2014). In particular, STI-based incubators support the transfer of technology and help promote STI-based entrepreneurship. STI-based incubators with close linkages with universities or research centers get (a) access to knowledge-based assets (such as technically-trained students and faculty) (e.g., Jaffe et al., 1993; Rothaermel and Thursby, 2005a), (b) help in incubatee startup survival (Rohtaermel and Thursby, 2005b), and (c) help for incubatee startups in developing networks (Lamine et al., 2016; McAdam et al., 2016; McAdam and McAdam, 2008). The linkages between STI-based incubators and universities not only have innovation-related outcomes but also help in implementing regional economic development goals as the localized clusters and regional networks formed promote entrepreneurial culture, information sharing, knowledge spillovers within and across firms and academia, and additional innovations (Saxenian, 1996).
While it is clear that incubator goals and activities dictate outcomes and ‘success’, there is no universal framework for assessing incubators (Phan et al., 2005). Incubators have been subject to extensive scrutiny worldwide in terms of their formation and function, their performance outputs and outcomes, and on their linkages with public and private actors (Bergek and Norrman, 2008; Dee et al., 2011; Hackett and Dilts, 2004; Phan et al., 2005). However, there is no consensus on what defines ‘success’—measures of success could include survival, sales growth, employment growth, innovativeness of incubated firms, or meeting goals of the public sector (Akçomak, 2009). A meaningful analysis of incubator activities therefore requires an understanding of the context for entrepreneurship (Autio et al., 2014), the underlying goals under which a specific incubator was set up (Bergek and Norrman, 2008), and the different incubation strategies or incubation business models applied in relation to various goals (Clarysse et al., 2005; Grimaldi and Grandi, 2005). Assessing the outcomes of existing incubators is critical for understanding the effectiveness of prevailing efforts and to justify future public spending in incubators for implementing SDGs.

2.3 Incubators for STI-based entrepreneurship in developing countries

Mian et al., (2016) shows that the large body of literature on publicly-funded incubators is largely based in industrialized countries of Europe or the United States. Less analyses exist on incubators in developing countries in part because of the lack of frameworks of assessment and the lack of clarity in metrics of success, couple with the stark differences in goals of individual incubators (see 2.2) and the differences in policy goals of promoting STI-based entrepreneurship (see 2.1).
Research on incubation programs in developing countries remains limited to few countries (e.g., Akçomak, 2009; Chandra and Fealey, 2009; Chandra and Silva, 2012; Lalkaka, 2002; Scaramuzzi, 2002; Tang et al., 2013). For example, in Brazil, incubators emerged when the government interventions in innovation shifted in the mid-1980s from the former military regime’s centralized large-technology projects to bottom-up innovation focusing on entrepreneurship at local and regional levels (Almeida, 2005; Chandra and Fealey, 2009; Etzkowitz et al., 2005). Brazilian incubators now have visible and active linkages to universities, industry, and government reflecting the ‘triple-helix’ model of synergies between these three stakeholders (Akçomak, 2009; Chandra and Fealey, 2009; Etzkowitz, 2002). In India, the government started to fund incubators since the mid-1980s as a means of developing STI-based entrepreneurial activity that would generate employment opportunities for a science and technology trained workforce (Lalkaka, 2002). In Chile, local governments collaborated with universities and industry to set up incubators since the early 1990s, paying particular attention to leveraging regional resources and to organizing risk capital and financing for early-stage startups as well as for incubators (Chandra and Silva, 2012). In contrast, incubators in China had a top-down mandate, with the government considering them as strategic avenues for technological advancement and economic development under China’s transition to a high technology-driven market economy (Chandra and Fealey, 2009). The government enabled STI-based entrepreneurship by heavily funding and subsidizing a large number of high-technology incubators and their incubatees (giving special attention to the returning Chinese diaspora) (Akçomak, 2009; Chandra and Fealey, 2009).

The emphasis on STI-based startups for implementing SDGs (2.1) and the role that incubators play in enabling conditions for these startups (2.2 and 2.3) calls for a systematic understanding of historical
incubator experiences in the context of developing countries for maximizing the effectiveness of emerging policies and programs.

3. Case context and approach
The rest of the paper focuses on India and analyzes the role of incubators in enabling STI-based entrepreneurship under evolving STI policy priorities.

3.1. Science technology and innovation in India
India is one of the world’s fastest growing economies but its multiple market failures mean that it does poorly in many societal and environmental aspects, e.g. human development, income inequality, and greenhouse gas emissions (Alvaredo et al., 2018; UNDP, 2018b). Balancing economic growth with sustainable development challenges is thus not only central to policymaking in India, it reflects the challenges many developing countries currently face or can expect to face as they grow.

Specifically, India is a suitable candidate for a case study on the role of STI-based incubators and startups for implementing SDGs because of three reasons. One, India has had over three decades of experience in linking STI with development goals that were recently formalized in the SDGs. While countries like Brazil and China also have had multi-decade experiences, the context in which incubators emerged and STI policy evolved in India is shared by many other developing and emerging economies—e.g. in its experience with economic liberalization reforms, emergence of multinational companies and their R&D centers, the return of IT-trained diaspora interested in exploiting new entrepreneurial opportunities, and in its efforts to match global trends in emphasizing new and emerging models of innovation through startups.
Two, India’s low score in various indicators of STI (Figure 1) and low levels of R&D investments, research personnel since the 1990s, and of patenting activity (Figure 2) are comparable to the situation in many other developing countries. Notably, apart from a few leading institutions, the state of India’s technical higher education is rather spotty – only up to half of the engineering graduates are seen as employable (CII et al., 2018; Tandon, 2017). While India has always been an entrepreneurial country known for frugal, flexible innovations (e.g., Radjou et al., 2012) and some widely cited reports suggest that its startup ecosystem follows that of the US or China (NASSCOM, 2015), not all entrepreneurial activities are associated with STI-based startups. While such startups generate revenues, create employment, and are important for supporting economic growth, they represent business model innovations rather than STI. This means that India’s low score in STI indicators, its low higher education capacity, as well as its poor outcomes in terms of STI-based startups are reflective of the situation in other developing countries, especially when compared to China where many of these metrics are significantly higher.

6 Despite the growing number of successful startups and entrepreneurs in India, not all entrepreneurs innovate in science and technology. Most commercially-successful Indian startups of the mid-2010s—for example, Naukri.com, Flipkart, Ola, Snapdeal, Zomato—have used established business ideas with proven international success and adapted them in the Indian market (see Raghavan, 2016).
FIGURE 1: India scores low in various indicators of innovation compared with other major industrialized and developing countries. Furthermore, all developing countries demonstrate weaknesses in human capital, education, and research as well as knowledge, technology, and creative outputs. Brackets next to countries show country ranking in the Global Innovation Index, 2017. Source: Cornell University et al., 2017.

FIGURE 2: Various indicators of science, technology, and innovation illustrate India’s continuously low inputs (e.g., (a) R&D investment), activities (e.g., (b) number of researchers) and outputs (e.g., (c) publications and (d) patents). Low R&D investments contribute to low number of researchers. And, even though science and technology publications have increased over time, they do not indicate an increase in STI given the small number of patents filed. Overall, India’s efforts are low compared to major economies such as South Korea and China where the emphasis on STI rapidly took off in the past decade. Source: World Bank, 2017
India’s STI-related activities (including but not limited to R&D) have specifically linked to economic and sustainable development-related goals and incubators have been particularly important in the implementation of that effort. This engagement has evolved from the post-Independence approaches since the early 1950s in more centralized R&D and technology transfer from large public-sector agencies, governmental laboratories, and large industries and private firms, to supporting specific sectors such as biotechnology or information technology (IT), and more recently to a decentralized emphasis on STI-based entrepreneurial startups since the 2000s. The importance of incubators is evident in the establishment of the National Science and Technology Development Board that set up incubator-like entities since 1985.

3.2. Approach

We conducted a detailed qualitative assessment of publicly-funded incubators in India and their role in enabling STI-based entrepreneurship and startups linked to SDGs. We used extensive archival research of government documents, conducted process tracing of policy-related activities, and conducted semi-structured interviews with a variety of stakeholders to inform our analysis (in Table A1 and Table A2 in appendix).

Given the importance of understanding the goals under which incubators were set up (Section 2), we first analyzed the evolution of public policy goals and activities for STI-based entrepreneurship, Next,

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7 These public institutions include (i) laboratories, e.g. the Council for Scientific and Industrial Research CSIR, (ii) large scientific agencies e.g., Department of Atomic Energy (DAE), Indian Space Research Organization (ISRO), (iii) public-sector enterprises e.g., Bharat Heavy Electricals Limited (BHEL), Hindustan Machine Tools (HMT), Indian Oil Corporation Limited (IOCL), and (iv) technical higher education institutions e.g., Indian Institutes of Technology IITs
we identified what public agencies did to enable policy goals. Finally, based on initial findings from our assessment of public policy evolution and interviews with key public agencies, we identified six incubators that implemented public policy goals related to social, economic, and environmental development using STI-based entrepreneurship and assessed how they were able to do so.

Our detailed assessment of the landscape of STI-based entrepreneurship aimed to understand key priorities and challenges from the perspectives of various actors under changing and evolving policy priorities. We found a systematic lack of data on public funding for incubator-related activities—both in terms of how funds were allocated and what have been the outcomes of public-funding or policy interventions. The lack of systematic data also made it difficult to systematically assess over time all incubators, their interactions with government and other actors, or their changing goals, priorities, outputs, outcomes etc. We partially addressed issues related to the lack of data by developed our own database from 1985-2014 of all publicly funded incubators that include public entities that received full or partial public-funding to support STI-based entrepreneurship. Because of the absence of a clear definition or metrics of incubator ‘success’, we relied on this research complemented by expert interviews to identify and qualitatively analyze six incubators that were largely perceived by interviewees as effective in meeting their goals related to SDGs (Table 2). While our six incubators are by no means an exhaustive representation of incubation activities in India, they represent incubators with a spectrum of goals, locations, and partners that reflect the various operating conditions that incubators in developing countries may face—i.e., in locations with access to different

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types of resources (e.g., location in metropolitan Tier I cities with extensive financial and industrial resources and networks vs. location in smaller cities or towns with limited resources or networks), different sector-related priorities (e.g., biotechnology vs. information technology), and different incubator partners (e.g., engineering university vs. business school). For each individual incubator, we conducted semi-structured interviews (see Appendix table A2 for a list of questions) with the goal of understanding incubator activities that had enabled implementation of SDGs.

| Incubator | Host or Partner | Location | Type of location |
|-----------|-----------------|----------|------------------|
| Center for Innovation Incubation and Entrepreneurship (CIIE) | Indian Institute of Management, Ahmedabad (IIMA) | Ahmedabad | Tier-1 city |
| Centre for Cellular and Molecular Platforms (C-CAMP) | Bangalore Biotech Cluster | Bangalore | Tier-1 city |
| Incubator at IKP Knowledge Park (IKP) | IKP Foundation | Hyderabad | Tier-1 city |
| Society for Innovation & Entrepreneurship (SINE) | Indian Institute of Technology, Bombay (IITB) | Mumbai | Tier-1 city |
| Startup Village (SV) | MobME, Government of Kerala | Kochi | Tier-2 city |
| Technology Business Incubator – Kongu Engineering College (TBI-KEC) | Kongu Engineering College (KEC) | Perundurai, Erode | Tier-3 city |

4. Results and discussion

An assessment of the historical evolution of STI policy provides insights into why incubators were set up (4.1), what various stakeholders involved in incubator activities did and what were the outcomes (in 4.2), and how they were able to implement SDGs (4.3).

8 Tier I cities are Delhi NCR, Hyderabad, Bangalore, Mumbai, Kolkata, Ahmedabad, Pune
4.1 Evolution of public policy for STI-based entrepreneurship

Our analysis of the evolution of public policy related to STI-based entrepreneurship (Table 3) finds evidence incubators have been vital to implementing goals directly related to Sustainable Development Goals 8 and 9—most prominently in supporting entrepreneurship and economic growth and supporting information technology (IT) and biotechnology industries. Incubators have been a part of the broader STI-based activities entrepreneurship agenda since the 1980s and continued to be a core part of policy priorities in the mid-2010s.

TABLE 3: Evolution of public policy goals for STI-based entrepreneurship and incubators in India. Source: Authors’ compilation from Five Year Plan (FYP) reports and other sources

| Period       | Announced plans and policies                                                                 | Broader policy goals for STI                                                                 |
|--------------|-----------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|
| 1980 – 1984  | • 1982: Department of Science and Technology (DST) sets up the National Science and Technology Entrepreneurship Development Board (NSTEDB)  
  • 1984: NSTEDB starts the Science and Technology Entrepreneurs Park (STEP) program          | • Generating employment for science and technology-trained workforce                          |
|              |                                                                                               |                                                                                             |
| 1985 – 1989  | • 1986: Government of India sets up the Department of Biotechnology (DBT)                     |                                                                                             |
|              | • 1987: DST sets up three pilot incubators with United Nations Fund for Science and Technology |                                                                                             |
|              |                                                                                               | • Generating employment for science and technology-trained workforce                          |
| 1990 – 1991  | • 1991: Government of India engages in country-wide economic liberalization reforms           |                                                                                             |
|              |                                                                                               |                                                                                             |
| 1992 – 1996  |                                                                                               | • Generating employment for science and technology-trained workforce                          |
|              |                                                                                               | • Training entrepreneurs for biotechnology                                                  |
|              |                                                                                               | • Commercializing indigenous technology                                                     |
| 1997 – 2001  | • 2001: NSTEDB sets up the Technology Business Incubators (TBI) program                       | • Regional development                                                                      |
|              |                                                                                               | • Training entrepreneurs                                                                    |
| 2002 – 2006  | • 2004: Indian Step and Business Incubator Association (ISBA) created                         | • Establishing interfaces between academia, R&D, and industry                              |
|              | • 2004: DST sets up the Technology Development Board (TDB) seed fund for financial support of startups | • Training rural populations in IT to encourage entrepreneurship                            |
|              |                                                                                               | • Supporting grassroots innovation                                                          |
|              | • 2004: INR sets up the Technology Incubation and Development of Entrepreneurs (TIDE) scheme for supporting electronics, IT startups | • Developing biotechnology through creating a venture capital fund, commercializing technologies, creating incubators and science parks |
| 2007 – 2011  | • 2007: DST incubators and incubatee startups are exempt from paying service tax              | • Supporting STI-based entrepreneurship                                                     |
|              | • 2008: Department of Electronics and Information Technology (DeitY) launches the Technology Incubation and Development of Entrepreneurs (TIDE) scheme for supporting electronics, IT startups | • Fostering academia-industry linkages;                                                   |
|              |                                                                                               | • Commercializing technology developed at universities using incubators                      |
|              |                                                                                               | • Supporting startups financially by facilitating venture funding and tax incentives         |
|              |                                                                                               | • Encouraging entrepreneurs through flexible salaries, startup grants                       |
|              |                                                                                               | • Supporting biotechnology through incubators, parks, and clusters, and through public-private partnerships |

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For three decades, incubators and startups were central to STI policy, first in their perceived ability to generate employment through supporting new enterprises (1980s), then in building academia-industry linkages and supporting technology transfer (early 2000s), and then in the specific endeavor to promote startups (2010s onwards). In the early 1980s, to encourage STI, the government engaged in incubator-building programs as it set up the administrating body, the National Science and Technology Entrepreneurship Development Board (NSTEDB) in 1982, that continues to administer publicly-funded incubators to date. The first incubators were set up to generate employment through Science and Technology Entrepreneurs’ Parks (STEPS), established prior to the economic liberalization reforms of the early 1990s when economic growth was particularly low and the innovation system particularly weak. The general paucity of innovation and entrepreneurial activity attracted regular firms interested in the basic infrastructures that STEPs offered (e.g., space and an improved supply of water and electricity) rather than STI-based startups (Mittal, 2015). These regular firms did not graduate as
incubatees even after several years, thus contributing to financial challenges and the systematic failure of the STEP program (DST, 2014).

By the early 2000s, a new program for Technology Business Incubators (or TBI) focusing on STI-based startups built on learning from past experiences and shortcomings of the STEP program as well as from other failed pilot incubators. Meanwhile, STI capabilities had grown because of the pairing of liberalization reforms of the early 1990s that led to greater availability of technology (as import tariffs lowered) with the increase in IT-trained talent (through reverse brain drain after the global dot-com bubble of the late 1990s). Incubators became a core part of STI activities, as reflected in the creation of an incubator association or Indian STEPs and Business Incubators Association (ISBA) designed to foster networks and to share best practices (Ministry of Science and Technology, 2004).

In the late 2000s and early 2010s, the public policy goals of strengthening linkages with industry and encouraging STI-based entrepreneurial activities generated new incentives channeled through incubators. Publicly funded incubators and their tenant incubatee startups became exempt from paying service tax in 2007. In 2013, the Corporate Social Responsibility (or CSR) program included spending on publicly funded incubators in its scope of activities related to social goods—the CSR program required corporate companies with high net worth and profits to spend two percent of their profits on social issues (Companies Act, 2013).

9 Of the 16 STEPs that were established between 1984 and 1995, only 6 demonstrated results or financial sustainability by 2001.
10 Incubators had been established in 1987-1990 by the United Nations Fund for Science and Technology (Lalkaka, 2002)
With this rich experience in setting up incubators, policies and programs enacted since the mid-2010s raised their ambition in linking STI with SDGs with the support of STI-based incubators. National- and state-level policies and programs emerged that specifically targeted the creation of new enterprises and innovation (e.g., Make in India, Startup India, Atal Innovation Mission, the National Entrepreneurship Policy, and the National Policy on Skill Development and Entrepreneurship) and the promotion of industry development, especially for biotechnology. Startup India primarily targeted practical barriers to innovation through: (i) easing of complex, lengthy regulatory processes for startups, (ii) providing high-risk funding and tax incentives to startups (with a total budget of INR 100 billion to be distributed by 2020), and (iii) promoting industry-academia linkages including through 70 new incubators, startup centers, and research parks (Ministry of Commerce and Industry, Government of India, 2016). The Atal Innovation Mission aimed to address social and economic development issues through STI by: (i) building the capacity to innovate in middle- and high-school students through 500 new maker-spaces known as Atal Tinkering Labs, (ii) creating 100 new sector- or technology-specific incubators, and (iii) extending support for existing incubators. While these policies and programs collectively targeted an intensification of incubator activity, they were built in an absence of lessons learnt from past experiences.

4.2 Implementing policies: characterizing publicly-funded incubator activity

A multitude of public agencies were involved in implementing the various STI policy goals related to setting up incubators. The activities and characteristics of these agencies—i.e. what they did—influenced the outcomes of incubator programs managed by these agencies as well as the outcomes of individual incubators that they funded.
Our assessment shows that government ministries and departments implemented policies in support of STI-based entrepreneurship and related SDGs in two ways. First, government departments—most prominently Department of Science and Technology (DST) through the National Science and Technology Entrepreneurship Development Board (NSTEDB), and the Department of Biotechnology (DBT) through the Biotechnology Industry Research Assistance Council (BIRAC)—engaged in developing incubators. Several other governmental departments indirectly supported existing incubators to enable STI-based entrepreneurship in order to promote a particular sector (e.g., IT) or to advance a particular agenda (e.g., promotion of small and medium enterprises) (Upadhyay et al., 2010). Second, government departments supported startups and entrepreneurial activity by providing access to government funding for those startups that were located in publicly-funded incubators (rather than private accelerators which are not part of this study). Startup incubatee had access to governmental financing designed for startup survival until the technology demonstration stage before STI-based startups were investment-ready.

The approaches used differed between departments. The DST promoted STI-based startup creation across all sectors through the NSTEDB. NSTEDB solicited applications for setting up incubators, and approved those that were set up with a partner ‘host’ institute (i.e., a university or R&D center)

1 The Department of Scientific and Industrial Research (DSIR) with its mandate of advancing industry-centric research and innovation ran a grants funding program for incubators—Promoting Innovations in Individuals, Startups and MSMEs, or PRISM. The Electronics and IT Department (DeitY) focused on electronics and IT-related industries and digital services by offering financial support to existing incubators through the Technology Incubation and Development of Entrepreneurs (TIDE) scheme. The Ministry of Micro Small and Medium Enterprises (MoMSME) collaborated with host institutes to designate incubator-like entities that encouraged early-stage ideas in a range of sectors (biotechnology, nanotechnology, fruit processing, ceramics, surgical instruments, etc.) (MoMSME, 2010). Others include the Ministry of New and Renewable Energy (MNRE), the Department of Industrial Policy & Promotion (DIPP) of the Ministry of Commerce and Industry, and several state departments.
among other criteria (NSTEDB, 2012a). Once approved, the NSTEDB provided initial financial support for five years for setting up and managing the incubator. In addition, DST provided funding for startups located in its incubators through the Technology Development Board and the Seed Support System that provided financial assistance (through debt, equity share, or a share of royalties) to technology-focused startups physically located in government-approved incubators (NSTEDB, 2012b).12

The DBT supported innovation through BIRAC, a public-sector enterprise for facilitating creation of biotechnology-based startups and converting research into products. BIRAC implemented the Bio- Incubators Support Scheme that aimed to create new incubators and to strengthen established, proven incubators. In addition, BIRAC provided financial support for entrepreneurial activity through several funding mechanisms—e.g., the Biotechnology Ignition Grant for developing early stage proof-of-concepts and the Small Business Innovation Research Initiative for growth. The Biotechnology Ignition Grant required applicants to be an incubatee in an eligible DBT incubator or to have a registered company with a functional R&D laboratory. In general, the DBT focused on the specific needs of innovation the life sciences industry—e.g., (i) long gestation period for startups (about five years) (ii) high capital intensity of technologies; and (iii) need for highly-skilled workforce to operate technical equipment.

12 The NSTEDB provided over INR 2 billion in funding for incubators, evolving from around INR 2 million for each incubator in the late 1980s, to an average of INR 30 million by 2015 (Gupta, 2015).
The outcomes of policy goals (4.1) and implementation activities related to STI-based entrepreneurship resulted in at least 140 incubators that received public funding through different central government agencies between 1985 and 2014. Of these, at least 86 Technology Business Incubators (TBI) and Science and Technology Entrepreneurs Parks (STEP) received funding from the NSTEDB (DST, 2014), making it the single largest supporter of incubators. Notably, we found the data on the number of incubators, their activities and funding sources, and their outcomes to be highly inconsistent (Table 4), and we therefore point out that the estimate of at least 140 publicly-funded incubators is based on our own in-depth assessment and data development.

Our analysis of the existing publicly-funded incubators in India reveals several shared characteristics in how incubators operate and how they link the various components of the innovation system. *First*, incubators operate as a not-for-profit entity (as a registered society), or as a company that is required to reuse profits or income and cannot provide any dividends to shareholders (a Section-25 company). *Second*, most incubators are set up with a host academic institute or a R&D laboratory with the expectation that the host can provide technology infrastructures needed for STI along with space and...
other basic facilities. 84 percent of NSTEDB incubators have such a host partner (DST, 2014). Third, incubators facilitate financing for startup incubatees through several direct public funding channels that are designed for startups located in government-approved incubators (See Figure 3); incubators also indirectly support funding by attempting to strengthen networks with private investors, angel investors, venture capital, etc. Fourth, incubators receive five years of financial support from the DST, after which they are expected to sustain their own business (DST, 2014). Other government departments also have some provisions for incubators to manage their expenses (Figure 3). Most incubators generate revenues by renting out infrastructures or by providing services to tenant enterprises. The managers choose their business models. And fifth, most incubators are in clusters around metropolitan Tier 1 cities that have strong industrial presence. When located outside of these clusters, incubators specifically aim to contribute to regional development while generating STI-based entrepreneurship.

FIGURE 3: The network of publicly funded incubators in India and their funding sources shows that most incubators are funded by multiple sources (including those analyzed in this paper); these are represented by larger size circles. Funding sources after 2014 (such as Atal Innovation Mission) are not included.
Despite the large presence of incubators in urban metropolitan clusters with strong industry presence, we found that the actual linkages of most incubators with industry had been weak (with the general exception of DBT incubators (Aggarwal and Chawla, 2013) and some DST incubators). Public policy interventions on strengthening these linkages have been ineffective. For example, the eligibility of publicly funded incubators for Corporate Social Responsibility spending was inconsequential for strengthening incubator-industry linkages as corporate firms preferred to finance more popular social values in support of government initiatives (e.g. Swachh Bharat Mission related to clean water and sanitation) rather than contribute to incubators. Furthermore, when existent, incubator relationships with industry were not through Indian public sector units or domestic firms but through large multinational corporates interested in developing domestic technologies for strengthening their supply chain networks.

4.3 How incubators implemented STI-based entrepreneurship for SDGs
Our detailed analysis of six incubators identifies six common features that show how incubators were successful in enabling STI-based entrepreneurship and implementing SDGs. We found that incubators primarily implemented Goal 8 and Goal 9 and did so when incubator activities extended beyond the regular incubator functions (described in section 2.1). We summarize these extended activities in Table 5 and discuss them in the following.
TABLE 5: Incubator activities in our case studies that enabled STI-based entrepreneurship for SDGs

| Incubator                                      | Attracting innovators                                                                 | Addressing unmet market demands | Providing financing for startups                     | Building networks for startups | Managing incubators effectively | Illustrative list of Sustainable Development Goals implemented (with some specific aspects) |
|-----------------------------------------------|--------------------------------------------------------------------------------------|---------------------------------|------------------------------------------------------|------------------------------|--------------------------------|------------------------------------------------------------------------------------------|
| Center for Innovation Incubitation and Entrepreneurship (CIIIE) | • Using networks and resources of host business school<br>• Engaging in capacity building activities in business school as well as in the country | • Incubating firms in sectors that meet societal needs | • Investing directly in startups<br>• Facilitating DST financing | • Utilizing business school networks<br>• Offering virtual mentoring / incubation | • Generating revenues from seed fund, management fee<br>• Improving operations with internal evaluation | Goal 2 (agriculture), Goal 3 (health), Goal 7 (energy), Goal 8 (economic growth) |
| Startup Village (SV)                           | • Partnering with local government<br>• Engaging in capacity building                |                                 | • Investing directly in startups<br>• Facilitating DST financing |                               | • Generating revenues from seed fund, management fee, private sector | Goal 8 (economic growth) |
| Society for Innovation & Entrepreneurship (SINE) | • Using networks of and resources of host engineering school                          |                                 | • Incubating firms focusing on product-based IT<br>• Facilitating DST financing |                               | • Partnering with local industry association<br>• Maximizing revenue through lean operations | Goal 9 (research and development) |
| Technology Business Incubator - Kongu Engineering College (TBI-KEC) | • Engaging in capacity building activities in engineering school<br>• Partnering with local industry |                                 | • Facilitating DST financing                          | • Partnering with local industry association<br>• Supporting networking by proving a mentor on board, organizing forums and events | • Generating revenues from technology platform licensing fee<br>• Improving operations with internal evaluation | Goal 8 (economic growth), Goal 9 (IT industry) |
| Centre for Cellular and Molecular Platforms (C-CAMP) | • Engaging with research and industry cluster<br>• Managing and distributing prestigious grants | • Incubating firms focusing on life science and biotech needs | • Facilitating DST, BIRAC financing<br>• Supporting networks by proving a mentor on board, organizing forums and events |                               | • Generating revenues from technology platform licensing fee<br>• Improving operations with internal evaluation | Goal 9 (biotechnology and life sciences industry) |
| Incubator at IKP Knowledge Park (IKP)          | • Engaging with research and industry cluster<br>• Managing and distributing prestigious grants | • Incubating firms focusing on life science and biotech needs | • Investing directly in startups<br>• Facilitating DST, BIRAC financing | • Offering virtual mentoring<br>• Generating revenues from seed fund, management fee, grant management<br>• Improving operations with internal evaluation |                               | Goal 9 (biotechnology and life sciences industry) |
4.3.1 Identifying and attracting innovators

Public policies for STI-based entrepreneurship had historically focused on the creation of incubators but had put limited emphasis on building capacity for STI-based entrepreneurship (see Table 3). This led to a gap between incubators’ high demand for quality ideas and innovators and the low supply of innovative, cutting-edge, technical ideas that were a consequence of insufficient talent, weak STI capacity in Indian academic institutions, and the relatively low understanding of markets and sectors relevant for sustainable and economic development goals (described in Section 3). Incubators that were able to successfully implement sustainable development related goals did so by addressing this gap by engaging in capacity development activities or by benefitting from the presence of well-developed human capacity.13

Three incubators CIIE, Startup Village SV, and TBI-KEC used the resources of their host partners while engaging in capacity building activities to attract innovators and develop ideas. CIIE’s association with a business school of ‘National Importance’ (Indian Institution of Management Ahmedabad) offered it access to skilled students and networks related to businesses and market-needs in and beyond STI. CIIE further developed this resource by focusing on innovation-specific capacity

13 In India, while the government recognizes the need for building capacity among students and academic researchers, existing government-led efforts have been largely insufficient for reaching the number of students and researchers necessary for enabling transformational change. For example, existing plans under the Atal Innovation Mission to build 500 Tinkering Labs stand to benefit less than 0.7% of 72,000 senior secondary schools. Similarly, plans to build 300 university-affiliated incubators will benefit less than 40% of over 770 universities. Furthermore, faculty and researchers in most universities lack incentives to generate market-driven ideas—faculty hiring and promotion has been based on guidelines set by the University Grants Commission (UGC) that prioritized degrees and publications (UGC, 2016, 2013). In 2016, UGC guidelines for evaluation or promotion focused on publications and included patents, but did not specify entrepreneurship or startups as favorable indicators of success for faculty evaluation and promotion. Also, UGC rules for ‘study leave’ mainly supported research projects only and did not allow full- or partial- employment with any organization during the study leave period, possibly due to potential conflict of interest.
building activities. For the business school, CIIE offered internship opportunities at the incubator, fellowships for student-entrepreneurs, prototype grants to offset concerns on education loans, and specialized courses (e.g., on mock fund management, technology and design). Outside the business school, CIIE attracted nation-wide ideas by hosting competitive programs (e.g., Power of Ideas) or by managing sector-based accelerator programs that addressed market-specific needs for sustainable development. Similarly, Startup Village SV engaged with the state government and helped make innovation a priority for the state (through the Kerala Innovation Policy). Furthermore, SV prioritized capacity-building in its region to ensure the supply of innovators in the long-term, for example by advocating for and helping implement a program providing open-source electronics prototyping kits to selected school students to encourage experimentation and building innovative products. Finally, TBI-KEC in a regional engineering college away from a major metropolitan city managed to attract innovators and market-driven ideas despite limited resources. TBI-KEC countered its modest geographically-linked STI resources by engaging in capacity building activities—for example, offering training in entrepreneurship and organizing workshops for students and researchers to strengthen skills in specific IT areas (e.g., Very-Large-Scale-Integration (VLSI) design, embedded technologies). TBI-KEC complemented capacity building activities to attract innovators by engaging with local industry associations in the closest city (i.e., Coimbatore) and participating in industry-specific trade fairs.

The three other incubators with a well-defined emphasis on STI activities relied on the resources of their partners or on their location to get access to good ideas and human capacity. In the case of SINE, its association with an engineering ‘Institute of National Importance’ delivered access to skilled engineering students, researchers, and alumni networks. The life sciences incubators’ (C-CAMP and
IKP) were built in physical proximity to biotechnology research and industry clusters that ensured access to scientific innovation and entrepreneurs. The access to knowledge and incubatees extended beyond their physical locations as these incubators managed or distributed several early-stage startup grants (e.g., from Biotechnology Ignition Grant, Bill and Melinda Gates Foundation) that attracted incubatees from the country.

### 4.3.2 Addressing unmet market demands

The policy goals for STI-based incubators (Table 3) targeted supply-side efforts—i.e., supporting technology push (e.g., for IT or biotechnology sectors or for general technology transfer) rather than identifying demand-side areas (e.g., those related to SDGs) and using incubators to support demand-driven startups. Successful incubators that we assessed had purposefully-defined goals related to addressing market failures and meeting unmet demand, especially in relation to implementing SDGs.

CIIE and TBI-KEC emphasized heavily on addressing market needs. CIIE’s market-oriented approach focused on assessing the viability of new products in underdeveloped sectors and in markets relevant for implementing SDGs. Through its various accelerator programs, CIIE used its understanding of business, markets, and market failures in sectors with high societal impacts (including agriculture, water, and clean energy). These accelerator programs aimed to find a product-market fit for advanced-stage innovators who had already developed prototypes or products by connecting them with potential stakeholders, customers, or investors. Similarly, TBI-KEC identified specific market demands and built its capabilities in electronics and information technologies to address these demands, ensuring success despite the challenges related to its limited geographically-linked resources.
The life sciences incubators (C-CAMP and IKP) focused on developing STI in a particular industry, i.e., biotechnology. These incubators recognized the sector specific needs of biotechnology that are unmet by market forces—such as the need for resources in the form of special equipment and laboratory facilities, or the need for more time (compared to IT) to demonstrate market potential. The added resources needed for biotech startups are difficult to obtain worldwide but more so in developing countries, given that private investors prefer less capital-intensive, low-risk IT that can provide short-term returns. These incubators therefore addressed specific challenges for biotechnology and life science startups by offering targeted mentoring, equipment, technical expertise, and industry linkages.

4.3.3 Providing access to financing for startups

Incubators that were successful in implementing sustainable and development related goals actively facilitated early-stage investment in risky STI-based startups by directly administering funding for startups from government bodies (see section 4.2) or by developing the incubators’ own seed funds (besides helping attract external investment, as described in 4.2).

IKP, CIIE, and SV were eligible to directly invest in early-stage incubatee startups and were registered investors with Securities and Exchange Board of India (SEBI). CIIE ran its own seed fund, Infuse Ventures, to provide early stage funding for clean energy startups. IKP helped set up the India Innovation Fund for investing in early-stage startups in the life sciences. These investments mutually benefitted both incubators and startups—in incubators with financial investments in startups were more deeply engaged in startup success while the reputation of these handful of successful incubators potentially also had a positive signaling effect in attracting later-stage private investments for the
startups they were associated with. For example, in CIIE, eighty percent of the incubatees received follow-on financing from venture capital or angel investors within two years of incubation.

Other incubators facilitated startup financing by implementing public funding schemes related to DST, DBT, and others (Figure 3), besides engaging in the traditional incubator function of enabling external financial networks. TBI-KEC offered loans to startups through the DST and did not take any equity. Incubators in the life sciences (IKP and C-CAMP) administered BIRAC grants to incubatees along with distributing other grants (e.g., grants from the Gates Foundation). SINE’s location in Mumbai, that is both a financial hub and an emerging startup cluster, provided easy access to venture capital for incubatee startups, with more than 50 percent of incubatees receiving investments from angels, venture capital, and financial institutions.

4.3.4 Strengthening startup networks

Providing startup incubatees access to multi-faceted networks is a core incubator activity worldwide (2.2) but was particularly in India where market failures (2.1) made it harder for STI-based startups to have adequate resources or infrastructures, or links with potential investors and potential markets. These networks for knowledge (including technical, strategic, operational, and market knowledge), mentorship, finance, and private sector markets played a vital role in incubator success. TBI-KEC exemplified the importance of networks in a non-metropolitan region—incubatees benefited from the incubator’s close ties with the local industry association (Coimbatore District Small Industries
Association) whose chairperson permanently served on the board of the incubator. CIIE, IKP, and SINE utilized their networks to ensure meaningful mentorship for incubatees. C-CAMP emphasized on market linkages and exposure to business ideas for its startup incubatee scientists through mentor forums and events. Incubators like IKP and CIIE also offered startups access to knowledge networks by supporting business plans, technology licensing, compliance requirements, intellectual property, etc.

4.3.5 Managing incubators effectively

The implementation of public policy goals to expand the number of STI-based incubators (section 4.1) lacked direction on how these incubators would be managed, especially given the risks faced by STI-based startups and the market failures related to SDGs (Section 2.1). We found that a key determinant of success was the clear development of management direction that transpired from the ability of incubator leadership (managers, managing team, founders, or trustees of the incubators) to effectively develop critical incubator activities pertinent to STI-based startups and SDGs (described in 4.3.1-4.3.4) while supporting incubator operations.

The importance of managers and management strategy manifested in three ways. One, experienced and effective managers were better able to work cohesively with different government departments, innovators, academics, and local industries to deliver economic and sustainable development outcomes from incubator activities. The experience managers in the six more successful incubators had worked in the private or public sectors or had graduated from a top-ranked university with strong

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14 With the help of networks of the industry association, the first product launched out of the incubator was an industrial vacuum cleaner part for Hacko (a German company)
alumni networks. In contrast, managers in less successful incubators were often professors adept at scaling-up or managing technology but lacking in experience in high-risk activities or in connecting STI with market needs. Two, effective managers had the skills to manage incubator finances and develop business models that ensured long-term financial stability and a secure flow of income for the incubator. The five-year timeline of financial support from DST was at odds with supporting STI-based entrepreneurship, given that most early-stage startups need time to develop their products and to yield financial returns. Consequently, while many incubators in the country struggled to be financially sustainable, the six incubators that we analyzed managed to generate revenues or to minimize costs using different business models. Incubators with their own seed fund (i.e., IKP, CIIE, and SV) charged a fund management fee to ensure sustainable revenue generation. IKP and C-CAMP complemented incubation activities with income generated through other sources—e.g., IKP charged a fee from foundations for managing grants and a fee from companies needing specialized biotech equipment; C-CAMP charged a licensing fee from users of its technology platforms. CIIE and SV also effectively mobilized private sector investments—e.g., CIIE’s accelerator program (iAccelerator) had financial support from Microsoft; SV raised nearly INR 25 million of investment for the incubator from the private sector as matching funding. Incubators like TBI-KEC engaged in lean operations—i.e., less staff members with multi-faceted skills—to minimize costs and maximize revenues. Three, effective managers engaged in regular self-assessment exercises and in adjusting activities and outcomes to improve performance. While DST had no formal or standard reporting requirements on incubator performance, CIIE held regular internal reviews that served as guidelines for changes in its activities in accordance to demand-side market needs especially related to SDGs. In contrast, DBT rigorously monitored the performance of IKP and C-CAMP, resulting in efforts to develop metrics for self-assessment and to find opportunities for improvement in economic and sustainable development outcomes related to STI-based startups.

15 For reference, most private equity firms that invest in risky ideas have a ten-year fund, and consequently, a ten-year investment horizon.
5. Implications for STI-based incubators for implementing SDGs

Developing countries have recently renewed the emphasis on enabling STI-based startups with the help of various configurations of incubators. For example, in the early 2010s, led by their respective governments, “Start-up Brasil” and “Start-up Chile” launched incubator-like programs aiming to attract local and international entrepreneurs. China continues to fund incubators because the push to enable STI-based entrepreneurship, especially from universities, continues to come from the highest levels of the government (Lu, 2015). Furthermore, even in Kenya, Nigeria, Zimbabwe, and Rwanda where the emphasis on STI-based entrepreneurship is relatively new, planned incubator-like entities (hubs) are anticipated to play a tremendous role in the economic transformation of these countries despite various challenges associated with inadequate education and financing (Friederici, 2016; The Economist, 2017). India has had a similar renewal of incubator activity in recent years, for example in its goals of increasing the number of existing incubators through national programs such as Startup India (70 new incubators), Atal Innovation Mission (300 new incubators), and other state policies (see section 4.1).

Ensuring the effectiveness of upcoming incubators requires a deeper understanding of past incubator strategies, operations, and management. This is particularly important when the context of (and resources available to) incubators in developing countries can vary substantially, while meeting goals related to generating STI will require purposeful design (Barbero et al., 2014). But because of the shared challenges faced by many developing countries (discussed in Section 2), lessons learnt from an analysis of India—given its rich historical experience with STI-based incubators along the need to manage economic development with other developmental challenges—are valuable not only for the
country’s own future efforts in extending incubation programs but potentially also for other developing countries facing comparable challenges or developing new programs.

Our analysis building on the experience of India reveals four areas where public policy for incubators in developing countries can directly or indirectly support STI-based startups and entrepreneurship for the implementation of SDGs.

*First*, policymakers working on STI roadmaps for SDGs must ensure that capacity building for STI accompanies any efforts to develop additional STI-based incubators. Public policy must focus on systematically broadening and deepening the pipeline of STI-based entrepreneurs rather than relying on scattered measures in place in some well-performing incubators to do so (examples in 4.3.1). Building capacity at the university level (in students, research, and faculty) is particularly needed in developing countries like India where universities are not the center of entrepreneurial activity (unlike in industrialized countries such as the United States) and universities are not strongly linked to innovation hubs (such as Silicon Valley). To begin with, this means strengthening science and engineering education. We do understand that the tail cannot wag the dog, i.e., concerns about more effective STI-based entrepreneurship cannot drive higher education policy by itself. But it also is imperative for policymakers to realize that efforts to boost STI-based entrepreneurship eventually are dependent on the quality of graduates. Next, for researchers and faculty, exposure to the ‘problem environment’ (e.g. the technology and market needs associated with specific societal goals such as energy access) can develop avenues for linking STI with a larger set of SDGs. When combined with incentives to promote entrepreneurship (e.g., sabbatical year for entrepreneurial activities and flexible human resource policies), such activities can broad-base STI-based entrepreneurship. Finally, for
universities, positive emphasis on startups can fundamentally change negative societal perceptions related to entrepreneurship (e.g., entrepreneurs-in-residence to act as role models to students16, extending university’s evaluation criteria to include university-based startups). In sum, effective capacity building in STI will be necessary for existing and new STI-based incubators to deliver outcomes related to the implementation of SDGs.

Second, policymakers can proactively use STI-based incubators as a tool to address market demand related to specific SDGs (see section 4.3.2). For example, governments could focus on designing incubators that have a purposeful objective of linking STI with market needs represented in SDGs (see examples in Table 1 related to energy access, health, sanitation, rural areas, water, agriculture, etc.). Such objectives could be enabled either through collaborations between government bodies or NGOs working with these issues and STI-based entrepreneurs17, or through the procurement processes in government agencies (such as ‘advanced market commitments’) for technologies that have significant social benefit. Furthermore, given the systematic underinvestment by the private sector in STI for societal goods, governments could use incubators to target public funding towards early-stage STI-based startups related to SDGs (examples in 4.3.3).

16 US universities engage in different activities to promote entrepreneurship among students by increasing interactions with successful entrepreneurs (see for example, MIT, 2016; Stanford, n.d.). For example, MIT invites successful alumni entrepreneur for one year (entrepreneur-in-residence) to guide students interested in founding startups in the developing world. Another example is the Mayfield Fellows Program at Stanford University that brings undergraduate students to Silicon Valley by offering them courses, mentoring and networking activities, and a paid internship at a startup in Silicon Valley.

17 For example, the Chicago CleanWeb Challenge hackathon provided city data to innovators and invited them to create technological solutions for environmental issues. In another example, the city government of Helsinki, helps startups by using technologies from cleantech startups including energy efficiency, low emissions public transport, waste management, district heating, water and air quality. Similarly, the local government in Sao Paulo, Brazil eased pre-qualification conditions for procurement tenders in favor of SMEs and startups. Sao Paulo also prioritizes procurement from startups as long as their bids are no higher than 10% of bids from non-startups.
Third, policymakers considering expansion of STI-based incubators in developing countries must also ensure that there is adequate managerial capacity to develop and lead incubator programs (4.2) as well as incubators (4.3.4). Program managers and incubator managers will together influence the implementation of STI policies through incubators. Program managers can enforce clear hiring criteria for incubator managers—e.g., a combination of science and technology, business, and managerial capabilities—before funding new incubators while offering training and advisory support for the management team. Both incubator managers and program managers can help in optimizing operations (e.g., by conducting periodic evaluations, aligning operational goals with SDGs) or in optimizing incubator business models (e.g., by developing public-private or competitive tendering processes to leverage long-term financing in incubators18, developing flexible sector-specific or performance-based financing programs for incubators).

Fourth, policymakers need to emphasize on systems-level coordination and assessment of existing incubator activities as they consider adding new incubators. Experiences from India show that a wide range of government programs and agencies engage in developing incubators, each with different policy goals. Coordination can help improve the effectiveness of individual government-led programs by minimizing overlaps and maximizing synergies, especially since our analysis shows that successful incubators tap into multiple public financial resources (see Figure 3). This coordination is necessary

18 Competitive tendering processes have been used to finance public-private incubators. For example, in Israel, the government implemented a public-private model for incubators by providing licenses to private equity, venture capital, angel investors, other industry, etc. through a competitive process. These incubator license holders financed 15% of the budget for a startup, and the government provided grants for the remaining 85%.
not only between government agencies (and program managers) but also between incubator managers—e.g., through forums, sector-specific meet-ups, networks of incubators—and can help in systematic sharing of knowledge, experiences, and generation of new ideas and networks among incubators and incubatees (Cooper et al., 2012). Top-down assessments of existing incubator programs could help define outcome metrics needed to assess whether sustainable development objectives have been met, followed by a systematic understanding of how to refine the overall approach towards incubation. Similarly, assessments of (technological/sectoral or regional) innovation system dynamics in a country along with assessments of market needs related to SDGs could serve as valuable inputs in defining incubator strategy. These could be accompanied by sector- or region-specific support services that are imperative for STI-based startups—including technical assistance (e.g., through ‘innovation vouchers’ that cover costs of such assistance), legal support for intellectual property and patenting, market research, or access to centralized government laboratories that help in testing new technologies. These activities related to coordination and assessment, while beneficial to all, are unlikely to be taken up by any single entity. Policymakers with a system-level perspective are therefore best positioned to ensure that these become part of STI policy implementation related to incubators.

19 For example, the Clean Energy Incubators Network in the US aims to highlight best practices on incubation techniques and clean energy technologies through workshops that bring together start-ups, incubators, investors, and industry participants working on clean energy.

20 The Indian STEP and Business Incubator Association already organizes such meetings, but these meetings need expansion and could be formalized to require all managers.

21 The validation of the technical performance of a new product by a government laboratory could help mitigate the perceived risk of investing in such a technology. For example, the Comprehensive Initiative on Technology Evaluation (CITE) is a USAID-funded program, where researchers at MIT develop consumer reports for new products (e.g., solar lanterns) provided by international aid agencies or private companies, to help consumers make informed choices of their purchases.
6. Conclusions

Publicly-funded incubators have been, and continue to be, a pivotal element in developing countries for promoting STI-based entrepreneurship and linking it to sustainable development goals—most notably Goals 8 and 9. Our findings suggests that incubators in developing countries are effective when their activities extend beyond ‘traditional’ incubator functions of providing infrastructures, networks, and services for startups. Developing country incubators need to engage in capacity building activities for developing and identifying entrepreneurial talent, in channeling public financing for startups, and in supporting areas related to specific SDGs (e.g., energy, health, etc.) that are beneficial to society and have high market demand but may not always be appropriately monetized by the private sector. Given this outsized role of incubators in developing countries, public policy for supporting STI-based entrepreneurship for implementing SDGs needs to focus on strengthening individual incubators as well as the ‘incubation system’. Additional research is needed to develop frameworks and approaches for systematically tracking data on public funding of incubators and incubatees, for identifying relevant metrics of success, and for appropriate monitoring and evaluation of incubators and programs and their links with different SDGs.

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Appendix

Table A1: Organizations involved with publicly-funded incubators in India that were interviewed for this study

| Organizations where interviews were conducted |
|------------------------------------------------|
| 1. National Science and Technology Entrepreneurship Development Board (NSTEDB) |
| 2. Department of Biotechnology (DBT) |
| 3. Biotechnology Industry Research Assistance Council (BIRAC) |
| 4. Indian STEP and Business Incubator Association (ISBA) |
| 5. Centre for Innovation Incubation and Entrepreneurship (CIIE) |
| 6. Centre for Cellular and Molecular Platforms (C-CAMP) |
| 7. IKP Knowledge Park (IKP) |
| 8. Technology Business Incubator at Kongu Engineering College (TBI-KEC) |
| 9. Society for Innovation and Entrepreneurship (SINE) |
| 10. Startup Village (SV) |
| 11. Incubator with a host research institute |
| 12. Incubator with a host large public university |
| 13. Incubator with a host large technical university |
| 14. Venture capital firm in India |
| 15. Academia (researchers in innovation and entrepreneurship) |

Table A2: Illustrative list of semi-structured interview questions

- What are the intended objectives for the incubator?
- What have been the envisaged activities to meet objectives?
- How have incubator activities changed over time?
- What have been the actual activities been carried out under those programs and by the incubators? And what might be the set of activities, a "successful" incubator must perform?
- What are the processes/determinants which lead to success or failure?
- How have incubators been able to strengthen the overall ecosystem?