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Linkages between the Indian Innovation System and MNE R&D Centers in India

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Abstract

The rise of developing economies (such as India and China) as new knowledge powers is reshaping the global innovation landscape. In a related vein, R&D has been increasingly globalizing beyond the triad region, multinational enterprises (MNEs) being the primary drivers of this shift, with India and China again emerging as prominent destinations for these transnational R&D activities. This article explores, through an analysis of scholarly and gray literature, along with semi-structured interviews of researchers and research managers in India, the landscape and dynamics of a broad range of linkages between MNE R&D centers in India and Indian higher education and research institutes, businesses, startups, and policy makers. We also focus on understanding how these linkages influence the technology innovation capabilities across the Indian innovation system. We then suggest key lessons and opportunities for Indian policy makers, university administrators, and MNEs, to expand and deepen the linkages and strengthen these capabilities.

Keywords

Multinational; R&D Centers; India; Innovation

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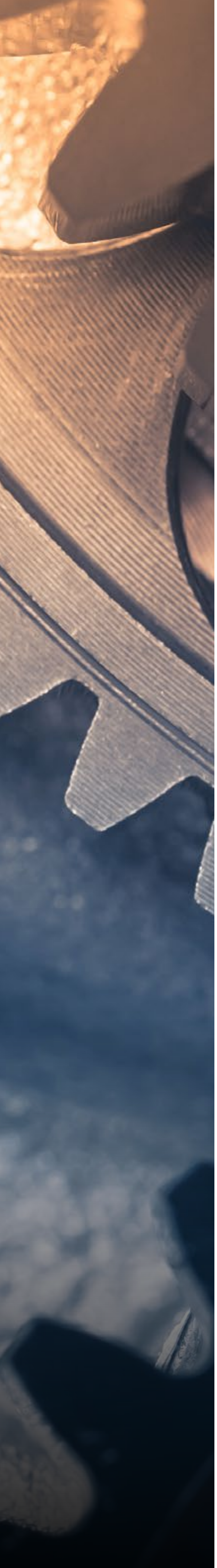
SUPPLEMENTARY MATERIAL



1. Introduction

Technology innovation has been recognized as central to the advancement of economic growth, in meeting sustainability goals, and, broadly, in promoting social wellbeing. It has been foundational in the developed countries' path to technological and economic leadership. Not surprisingly, developing countries around the world have been intensifying their efforts to foster technology innovation in order to accomplish their national ambitions and also address global challenges like climate change. These efforts have included greater expenditures on R&D[1]: China's gross expenditures on R&D (GERD) increased 10-fold between 2000 and 2016, and those for India, 4.4 times during this period, while the OECD increased its GERD by 50% (all in US dollar terms).[2] China and India now rank 2nd and 7th, respectively, in terms of national GERD, ahead of many OECD countries. Thus, major emerging economies have begun to be viewed also as emerging knowledge powers. While the OECD still remains the dominant performer of R&D globally, the rise of these knowledge powers has resulted in a shift of the global technology innovation landscape.

A concomitant major shift has been the growing globalization of innovation through the expansion of transnational R&D efforts. While globalization of R&D also includes growing international collaborations among universities (Wagner, Park et al. 2015) and national labs, MNEs are the main drivers of globalization of R&D, as the top 90 R&D-investing MNEs in the world accounted for a fifth of global R&D expenditure in 2015-16[3]. As part of this shift, these MNEs have also been expanding their R&D activities beyond North America, Western Europe, and Japan (referred to as the "triad region"), to developing countries such as China and India.

In fact, since the turn of the century, India and China have been among the most attractive destinations for R&D centers (R&DCs) of

1 R&D: "Research and experimental Development" as defined in the Frascati Manual (OECD 2015).

2 Author calculations from OECDStat, GOI Research and Development Statistics 2017-18, and World Development Indicators.

3 Authors' calculations from data in (European Commission 2015) and (R&D Magazine 2016).

MNEs from developed countries (Kekic, Lofthouse et al. 2004, UNCTAD 2005) (Tübke 2015). Their large technically skilled talent pools available at significantly lower costs than developed countries, the presence of a few globally competitive innovation hot spots and enormous growing market opportunities make these countries attractive destinations for MNE R&D activities (Mrinalini, Nath et al. 2012) (Tübke 2015) (Franco, Ray et al. 2011) (Grandstrand and Sjolander 1992).

While the MNE[4] R&D activities, in principle, add to the overall innovation in the host developing countries, they can have positive as well as negative implications for the innovation capabilities in the "host"[5] developing countries (refer to Section 2.2 for examples) (Pearce 2005) (UNCTAD 2005) (Wong 1999) (Reddy 2005). Whether local innovation capabilities benefit from these activities depends significantly on the existence and nature of linkages between the MNE R&DCs and, *inter alia*, universities, other firms, and policy makers in the host country. These linkages may include research collaborations between MNE R&DCs and local universities, mobility of researchers between MNE R&DCs and other local companies, or MNE researchers providing technical input to host country policy makers on technology policy issues.

In this paper, using India as a case study, we therefore focus on understanding the nature of various linkages between MNE R&DCs and the innovation system in host developing countries. We focus our analysis on unpacking key implications of the linkages for innovation capabilities in the host countries, along with lessons and opportunities for policy makers and administrators of higher education and research institutes (HERIs) in the host country and MNEs. This subject has not received due attention in the innovation literature (in contrast, the drivers of expansion of MNE R&D in developing countries (Marin and Arza 2009) and also management of offshore R&DCs of MNEs (Han 2008) have received much more attention). Detailed understanding of these linkages would be valuable for policy makers including R&D funding agencies and for HERI

4 Hereafter, the term "MNEs" will refer to foreign MNEs from developed countries, unless otherwise specified.

5 "Host" country is where MNEs only have subsidiaries, whereas "home" country is where they have the global headquarters.

administrators in developing countries. It could also be helpful for the MNE R&D centers to tailor their activities to improve local engagement.

While several studies have examined the MNE R&D landscape in China (Han 2008) (Wang 2014) (Von Zedtwitz 2004), the landscape in India has not been studied in as much detail. Further, the MNE R&D landscape in India is particularly interesting because MNEs have a much larger share in innovation activities in India than in China (Kamat, Sagar et al. 2019). Based on our analysis of data from the USPTO, MNEs accounted for 85% of all US utility patent applications with India-resident inventors during 2010-2014; 8 out of the top 10 patenting organizations from India were foreign MNEs; the corresponding numbers for China were 47% and 2 out of 10, respectively. The R&D intensity (i.e. R&D expenditure ÷ total sales) of US MNE affiliates in India (3.5%) is also well above their R&D intensity in USA (2%) and China (<1%), as well as their average R&D intensity outside the USA (<1%) (Kamat, Sagar et al. 2019).

This paper addresses the following two research questions:

1. What kind of linkages exist between MNE R&DCs and the Indian innovation system and in what ways do these influence the technology innovation capabilities of India's innovation system?
2. What steps can decision-makers, including those at R&D-funding agencies, HERIs, and MNEs take to contribute positively in this area so as to enhance capabilities in the technology innovation system[6] in India?

6 In this paper, we use the concept of "innovation system" to collectively refer to the network of a wide range of actors who participate in innovation process, through their individual activities and interactions with each other (linkages) (Lundvall, Joseph et al. 2009). These include higher education and research institutes, industry, and also policy makers, among others. Three of the core concepts of innovation systems thinking are that (i) innovation involves a multitude of actors, (ii) linkages among them are critical in innovation and in harnessing its full potential for the advancement of the economy, and (iii) these actors are embedded in an institutional landscape that shapes their activities and interactions and, in return, is shaped by them. These three concepts are central to this paper and to our working hypothesis that linkages between MNE R&DCs and developing countries innovation systems can be instrumental in the enhancement of innovation capabilities of the latter. Additionally, the discussion and analysis in this paper also touches upon other strands of the innovation literature, mainly globalization of R&D (UNCTAD 2005), management of innovation (Tidd 2005), and Global Value Chains (Pietrobelli and Rabellotti 2011).

This paper contributes to the scholarly literature on both nature and impacts of globalization of R&D as well as innovation in emerging economies in two ways. First, by developing an understanding of the dynamics of external linkages of MNE R&DCs in India, this paper addresses a gap in the literature—the MNE R&D landscape in India has not received much attention in the literature, even though India is an emerging knowledge power and a prominent location for MNE R&D activities. Secondly, our paper contributes to an understanding of the role of indigenous innovation capabilities as well as other factors influencing MNE R&DCs' linkages to the local innovation system and the impact of these linkages. Furthermore, this paper also aims to highlight ways in which key decision-makers within developing country government agencies and other innovation actors as well as within MNE R&DCs can actively enhance the linkages between the domestic innovation system and MNE R&DCs.

The rest of this paper is organized as follows. In the next section, we provide a brief overview of the Indian innovation system and internationalization of R&D. Section 3 details the methodology of the study. Section 4 describes the evolution of MNE R&D in India and key linkages between Indian innovation actors and the MNE R&DCs. In Section 5, we discuss first the important factors influencing these linkages and then lessons and opportunities for key decision makers based on our analysis. Section 6 concludes the paper.

2. Background

In order to contextualize further discussion, this section provides brief overview of key trends in the Indian innovation system and internationalization of R&D.

2.1 Overview of Indian innovation system

Science and technology (S&T) have historically been viewed as central to India's development. In fact, from its earliest days after independence from the British, national policy makers, including those at the highest level, recognized the relevance of S&T for a developing economy and accordingly directed their efforts at building up a vibrant S&T enterprise. This included setting up public S&T infrastructure, both in a network of national labs as well as establishment of agencies such as the Department of Atomic Energy (DAE) and the Indian Space Research Organization (ISRO), technology-oriented PSUs, and technical higher education institutes such as the Indian Institutes of Technology (IITs). While much of the emphasis in early years was on building domestic capabilities and enterprises for import substitution, the economic liberalization of India in 1991 led to new opportunities for reinvigorating the country's S&T enterprise through greater flows of knowledge, people, and products enabled by more-open borders, as well as an impetus to do so driven in large part by exposure to international competition. The approach to S&T has also evolved over this period, from the Industrial Policy Resolution of 1956 exemplifying the early approach to the policy statements to the development of an Innovation Policy document in 2013.

India's efforts to advance science, technology, and innovation capabilities, however, have seen mixed results. India ranked seventh among all countries in terms of the national GERD and eleventh in terms of the number of science and engineering research articles published[7] (UNESCO Statistics).

7 The ranking is based on the number of science and engineering research articles published with authors residing in each country (Clarivate Analytics).

With its successful lunar and Mars missions, ISRO is a strong competitor in the international satellite-launch market. It also has vibrant atomic energy R&D and deployment efforts, led by DAE. It is the top developing country (and 5th overall) in terms of exports of information and communication technology services. Two Indian IT services companies, Tata Consultancy Services and Infosys are among the 5 most valued IT services brands in the world (Brand Finance 2019). Between 2000 and 2015, the share of industry in India's national GERD increased from 18% to 43% (UNESCO Statistics). India awards more undergraduate university degrees in science and engineering than any other country (National Science Board 2018). With continued exponential growth over the last few years, India has the 3rd largest technology startup ecosystem in the world (NASSCOM 2018). Indian diaspora is exceptionally successful in science and technology research and careers in developed countries. One out of every six science and engineering doctorate holders in the USA was born in India (National Science Board 2018). Sundar Pichai (CEO, Google), Satya Nadella (CEO, Microsoft), Vinod Khosla (founder, Sun Microsystems), and Shantanu Narayen (CEO, Adobe Inc.) are a few examples of Indian-born heads of world's top technology companies, who also received their undergraduate education in India.

On the other hand, India ranked 57th in 2018 in the Global Innovation Index rankings, far behind USA (6th) and China (17th) (Dutta, Lanvin et al. 2018). Although technology innovation appears to be at the top of the government agenda, the country spends less than 1% of its GDP on R&D, much less than USA (2.79%)[8], China (2.07%), and also Brazil (1.17%) (UNESCO Statistics). There are only 216 researchers per million population in India—far less than USA (4313), Germany (4748), China (1159), and Brazil (900). The country also suffers from a severe "brain drain"—in 2011 (latest available statistics), 40% of Indian-born researchers were working abroad (Noorden 2015). While India is among the top 20 countries in terms of the origin of patent applications and granted patents for domestic applicants (WIPO 2015), it ranks much lower when the patent applications are counted relative to the GDP (Dutta, Lanvin et al. 2018).

8 GERD as % of GDP numbers are for 2015 for USA, China and India, and for 2014 for Brazil—2015 is the latest available data for India.

Therefore, in many ways, India remains a paradox. It has had a number of commendable accomplishments in several areas of science, technology and innovation. But this success is sparse and limited to few innovation "hot spots" relative to the scale of the economy: a few industrial R&DCs in a small number of industries, a few HERIs, and a few startup success stories. Even though it has many ingredients necessary to strengthen its technological capabilities and innovation competencies, it has not been able to move as swiftly as newly industrialized economies such as S. Korea, Taiwan, Singapore, or China.

2.2 Overview of internationalization of R&D

In 1980s, when a growing number of countries, like S. Korea, Taiwan, and Singapore, developed their specialized science and technology competences through increased R&D investments, MNEs started opening their core R&DCs outside the triad region, to support their production processes in, and to source knowledge and technologies from, these countries (Pearce 2005, Reddy 2005). Since 1990s, as the "offshoring" business model became prevalent (Reddy 2005, Lewin 2009) and as the economies of countries such as India and China grew, they attracted an increasing number of MNEs to set up and expand their R&D operations in these countries (Lewin 2009, Tübke 2015).

R&DCs established in developing countries by developed-country MNEs bring advanced innovation activities in closer proximity to the developing countries. They are closer to the technological frontier (because these MNEs often define it) as compared to the developing-country firms (Marin and Arza 2009). These R&DCs are closely integrated with global innovation networks that often span both the developed and the developing world. They also play a key role in "brain circulation" (Saxenian 2002, Saxenian 2005), especially in bringing researchers trained and experienced in technologically more advanced countries to the host developing countries. Thus, MNE R&DCs present promising opportunities for developing countries in the advancement of innovation capabilities and in pursuit of technological catch-up and innovation-driven economic growth (Pearce 2005) (UNCTAD 2005) (Wong 1999).

On the other hand, if these MNE R&DCs work on problems of little relevance to host developing countries, diverting already scarce host-country technical resources including R&D personnel from priorities of the local markets, then their activities would have limited or no benefit to the host country (Reddy 2005). The nature of R&D activities of these R&DCs along with existence and nature of their linkages with the rest of host innovation system, therefore, become important determinants of whether the innovation capabilities in the host country benefit from the MNE R&D activities.

The nature of R&D activities varies across R&DCs of an MNE, across MNEs, and across industry sectors.[9] The nature of these activities is also likely to influence whether an R&DC builds external linkages. Although R&DCs which mainly engage in low value-added R&D support MNEs' production activities in the host country and contribute to the aggregate technological base in the host country (Pearce 2005), they often work in isolation and are unlikely to build external linkages. Therefore, benefits of these MNE R&DCs to the host-country innovation capabilities are limited or even absent. On the other hand, those R&DCs which engage in more high-end and cutting-edge R&D have autonomy to plan their R&D and are more likely to build external linkages that are also more likely to be beneficial to both the MNE and the host country.

The host country's ability to benefit from MNE R&D activities also critically depends on the country's ability to identify, assimilate, and apply new knowledge and technologies, which requires a minimum necessary threshold level of human capital and local R&D capabilities (Cohen and Levinthal 1989) (Fu, Pietrobelli et al. 2011) (Li 2011) (Fu and Gong 2011).

In the rest of the paper, we explore the implications of MNE R&D for the Indian innovation system, with main focus on linkages of MNE R&DCs with other Indian innovation actors.

9 Some of the popular taxonomies of MNE R&DCs can be found in (Kuemmerle 1997) (Von Zedtwitz 2004) (Behrmann 1980) (Westney 1988) (Medcof 1997) (Reddy 2005) (Chen 2007) (Wang 2014).

3. Methodology

In order to gain insights into major trends in the MNE R&D landscape in India, we began with an extensive survey of scholarly and gray literature on this topic and sixteen semi-structured scoping interviews of experts and practitioners having experience in working at or interacting with R&DCs in India. These interviews covered several MNEs that have (or had, in the past) R&DCs in India, one of the top R&D-investing Indian companies, one of India's leading industry conglomerate, two top-tier Indian HERIs, an industry consortium of US MNEs with business operations in India, and an India-based technical forum. These interviews were conducted through phone or video calls, with mostly open-ended questions and each interview lasting for 30 to 90 minutes.

From the literature and interviews, we learned that, although there are hundreds of MNE R&DCs in India, only a few R&DCs, set up by some of the world's top R&D-investing MNEs (European Commission 2015), have strong external linkages, and many of these R&DCs are located around the city of Bengaluru in southern India. Therefore, for further study of MNE R&DC linkages, we selected several of these MNE R&DCs that are likely to have strong external linkages. We visited most of the MNE R&DCs and conducted detailed in-person interviews[10] of researchers, research managers, and (current and/or former) heads of these MNE R&DCs, all in Bengaluru. Additionally, we also interviewed researchers, research managers and heads of a Bengaluru-based R&DC of one of India's top R&D-investing company and two top-tier Indian HERIs, one in Bengaluru and the other in New Delhi. Each interview lasted for 30 to 90 minutes. The details of interviewees in the scoping and in-person interviews are included in Section A of the Supplementary Material.

The detailed interviews touched upon the following questions:

1. What is the nature of various research and innovation activities of MNE R&DCs in India? How have they changed over the years?

10 One interview at this stage was conducted on phone, since an in-person interview could not be scheduled.

2. What are different linkages that exist between the MNE R&DCs and other actors in the Indian innovation system, such as HERIs, Indian companies, startups, as well as policy makers? How have these linkages evolved over time?

3. What are the key implications of these linkages for technology innovation capabilities in India?

4. In what ways can policy makers, HERI administrators, and MNEs contribute positively to these linkages so as to enhance these capabilities?

Analysis of all the interviews revealed a number of commonalities and agreements among responses of the interviewees. We then conducted a more thorough survey of scholarly and gray literature, which included research papers, government reports, annual reports of universities, company websites and reports, and news outlets. The aim of the literature survey was to corroborate and supplement key findings from the interviews. This analysis focused specifically on developing an in-depth understanding of

1. the dynamics of various linkages of the Indian innovation actors with the MNE R&DCs,

2. the most important factors influencing the linkages, and

3. lessons and opportunities decision-makers, including those at R&D-funding agencies, HERIs, and MNEs could take to contribute positively to the linkages.

4. MNE R&DCs in India: An evolving story

In this section we present the results related to major trends in the MNE R&D landscape and linkages of MNE R&DCs in India.

4.1 MNE R&D landscape in India

Texas Instruments (TI) was the first MNE to set up an R&DC in India, in 1985 in Bengaluru[11] city, which was chosen to be close to the industrial cluster, where many MNEs already had their product development centers, and to the Indian Institute of Science (IISc), India's premier HERI. As an interviewee working with TI India since 1985 puts it:

> *"The fundamental reason why TI thought of starting an operation in India was that at that point of time both in England and … in Dallas (USA) we had big [R&D] centers… And we figured out that we have a lot of people from this region (India) who are actually… doing really good [work]… And that's the reason why TI thought that we'll explore this region and send some people here."*

In the last two decades, hundreds of MNEs have launched R&DCs in India. Based on the nature of their objectives and R&D activities, MNE R&DCs in India can be categorized as follows (using the MNE R&DC typology proposed in (Wang 2014) through case studies of MNE R&DCs in China):

1. Technology Competence Units (TCUs) perform core R&D in their specialized technical domains ("R" of R&D) and develop technologies with long-term horizon for the future global market. They are referred to as Corporate Technology Units in another typology (Pearce 2005).

11 Previously known as Bangalore.

2. System Competence Units (SCUs) identify market opportunities, define the products and services, design system modules and architecture, and integrate a variety of modules into final products and services. They have ownership of projects or products.

3. Support Units (SUs) focus on adaptive R&D, utilizing existing knowledge and technologies of the MNE to cater to the local market demand in the host country. These are similar to the Home-Base Exploiting R&DCs (Kuemmerle 1997) and Technology-Transfer Units (Pearce 2005) in other R&DC typologies.

4. Assignment Units (AUs) emerged out of the outsourcing or offshoring strategies, to perform the labor-intensive, cost-sensitive, and peripheral low-value-added R&D in developing countries, where the cost of R&D personnel and overall operations is significantly lower than in developed countries. (Lewin 2009) named them Home-Base Replacing R&DCs.

Early-comer MNE R&DCs in India in 1980s and 90s began as AUs or SUs, providing staff augmentation to R&DCs abroad or adapting products for the low-price preference of the Indian market. Many R&DCs of the world's top R&D-investing MNEs, such as General Electric, IBM, and Texas Instruments, later evolved into SCUs or TCUs, taking up more high-end R&D activities and becoming more autonomous in planning and budgeting their own R&D and gradually leading their parent MNEs' worldwide R&D efforts in specific technology areas and product lines. Many of them also host one of the global "centers of excellence" of their parent companies—e.g. Texas Instrument's center of excellence, named Kilby Lab-India, which is their first "Kilby Lab" outside the US.

According to the lead researcher of an MNE center of excellence:

> *"If somebody wants to operate in India [only] based on cost, then that's a lost model, because I don't think you can sustain that. The value that you bring in is really what is important. You can't bring that value overnight. You have to be at it…*
>
> *It took [early-comer R&DCs] 25-30 years to get to where [they] are… Newer organizations can accelerate that because there is an ecosystem, there is at least a proof that somebody else has managed to build world-class products here...*
>
> *The right leadership locally is also equally important… But [if] worldwide leaders in most of these [MNEs] would… look at India the right way, they'll see the right value."*

As MNE R&DCs took up more high-end R&D, they began hiring more PhDs. The leaders of most of the R&DCs (SCUs or TCUs) that we visited and a majority of their researchers with PhD are Indians who first completed undergraduate or graduate studies in India and then earned further studies and research experience in the US or Europe before returning to India. "Brain circulation" (Saxenian 2002, Saxenian 2005) has, thus, played an important role in the expansion of the MNE R&D landscape in India. Our interviews indicate that, because MNE R&DCs are likely to work closer to the technical frontier than R&DCs of Indian firms, they have been more successful at attracting Indian and foreign PhDs to India from abroad. Furthermore, those MNE R&DCs in India which have SCUs or TCUs, are more likely to build external linkages, given they have more autonomy to build such relationships, and their linkages are also likely more productive. However, all of our interviewees agreed that a large majority of MNE R&DCs in India are still functioning in SU or AU mode.

Activities of many leading MNE R&DCs in India have also diversified in the last two decades. These R&DCs are composed of multiple R&D units or research groups which can be separately categorized as TCU, SCU, SU, or AU. Thus, classification of an R&DC as a TCU or SCU means that it has at least one unit or R&D division which acts as a TCU or SCU.

4.2 Linkages of MNE R&DCs with the Indian innovation system

Table below lists key linkages of the MNE R&DCs with Indian HERIs, other firms including startups, and policy makers.

MNE R&DC's linkage with...	Linkage	Types of MNE R&DCs observed to build the linkage
Higher Education and Research Institutes	Short-term positions for students and researchers	TCU, SCU, AU, SU
	Research collaborations and funding	TCU, SCU
	Visiting and adjunct positions for MNE researchers and HERI faculty	TCU, SCU
Industry (other Indian companies and MNEs), excluding startups	Co-innovation	TCU, SCU
	R&D outsourcing	TCU, SCU
Startup ecosystem	Indirect engagement through other MNE divisions	TCU, SCU
	Direct mentoring	TCU, SCU
Policy makers	Engagement through industry consortia	TCU, SCU, AU, SU
	Direct engagement	TCU, SCU, only early-comer AUs/SUs in 1980s

Table 1: Key linkages of MNE R&DCs with the rest of the Indian innovation system.

4.2.1 **Linkages with the HERIs**

Short-term positions for students and young researchers: Several MNE R&DCs hire, mainly, master's and PhD students as interns for a duration of three to six months. Most of the PhD student interns are from IISc or the seven oldest IITs[12]. During internships, PhD student-interns typically participate in more advanced research projects compared to master's and undergraduate students. We learned from interviews that PhD student-interns facilitate research collaborations between their internship mentors at the R&DCs and PhD advisors at HERIs, which sometimes continue even after the internship has ended. In rare cases, MNE R&DCs also have a few postdoctoral researcher positions that last for one to two years.

R&D collaborations and funding: In recent years, R&D collaborations between MNE R&DCs and leading Indian HERIs, like IITs and IISc, along with a few research groups at the National Institutes of Technologies and Indian Institutes of Information Technology are growing (IISc 2015-16a) (IITB 2015-16) (IITD 2015-16) (IITK 2015-16) (IITKgp 2015-16) (IITM 2015-16). MNE R&DCs are also increasingly providing research grants to these HERIs.

Visiting and adjunct positions for MNE researchers and HERI faculty: Over the last decade, top Indian HERIs like IITs and IISc are offering visiting faculty positions to researchers from leading MNE R&DCs. On the other hand, very few MNE R&DCs, like GE's John F. Welch Centre, have visiting researcher positions for HERI faculties.

4.2.2 **Linkages with other companies in India (including other MNEs, excluding startups)**

R&D outsourcing and supplier capabilities building: Many MNEs outsource (generally low-end) part of R&D to other firms in India, thus using other firms as Supporting or Assignment Units. The R&DC manages the R&D segmentation to outsource a particular segment and, later, integration of

12 The seven oldest IITs are in Mumbai, Delhi, Kanpur, Kharagpur, Chennai, Roorkee, and Guwahati. Many newer IITs have been established since 2008.

its outcomes. This helps the R&D-service provider firms upgrade their technical capabilities, which typically follow, and hence lag, innovation capabilities of their clients. MNEs that entered a greenfield industry sector in India and needed to use the local supplier ecosystem, have had to help that ecosystem develop its capabilities. While the relationships with the supplier firms are managed by a business unit of the MNEs, its R&DCs often provide the technical resources and mentoring to the supplier firms.

Co-innovation: Traditionally, R&D units in firms did not have formal collaborations with their counterparts in other firms. In recent years, however, firms around the world have begun to collaborate with other firms with complementary capabilities right from the R&D stage—a trend often called "co-innovation". This trend of co-innovation is also growing in India, where MNE R&DCs collaborate with their counterparts in Indian companies and in other foreign MNEs within India or abroad. An example of a successful co-innovation is a wireless charging technology for electric cars that GE's John F. Welch Centre developed in collaboration with Mahindra Reva[13], the first Indian electric car company. (Based on our interviews, other examples of co-innovations exist, but are not publicly disclosed.)

4.2.3 **Linkages with the startup ecosystem**

MNEs or their Indian R&DCs conduct or co-organize innovation competitions, in which winning startups receive a monetary prize and an opportunity to work with the MNE or their R&DC to develop their technology further. "Google for Entrepreneurs", IBM, Amazon web services, Facebook, and Microsoft Accelerator are sponsors for NASSCOM's (National Association of Software and Services Companies) multiyear '10,000 startups' initiative (NASSCOM), and Texas Instruments has joined India's Department of Science and Technology (DST) to organize 'India Innovation Challenge'.

13 "*GE reveals wireless charging for electric vehicles*", https://shifting-gears.com/ge-reveals-wireless-charging-for-electric-vehicles/, Feb. 6, 2016, accessed August 12, 2019. We learned through an interview that wireless charging of electric cars is sensitive to the alignment between the car and the charger, making it less convenient, while the technology developed by GE and Mahindra Reva does not require such an alignment.

Besides these competitions, many MNE R&DCs engage with startups to evaluate the latter's technology, to mentor them, and to strategize how their technology can complement and integrate with the MNE's products and technology platforms. Because these MNE R&DC-startup relationships are commonly managed by venture capital and private equity divisions of the MNEs, the involvement of the R&DCs is limited. ZoomCar, a car-rental/car-sharing startup, is an example a successful startup (Back 2014) from Microsoft's Accelerator in Bengaluru, while Intel Capital is one of high-profile investors in Snapdeal —an Indian startup unicorn ("The Unicorn List 2016" 2016). Direct engagement between MNE R&DCs and startups is quite uncommon in India.

Many MNE researchers are also founding their own startups in India. In the early years of the Indian startup ecosystem the majority of startup founders were former employees of MNEs (including their R&DCs) (NASSCOM 2014). One notable example is Ola Cabs, an Indian startup unicorn in transportation network business, co-founded by a researcher previously working at Microsoft Research India. There are also examples of entrepreneurial spin-offs from MNE R&DCs. For example, Digital Green which began as a project of Microsoft Research India and was later spun off into a non-profit startup in the agricultural industry (Digital Green Website).

4.2.4 **Linkages with Indian policy makers**

Interactions between early-comer MNE R&DCs like TI and Indian policy makers played an important role in ensuring policies that enabled and facilitated the expansion of MNE R&DCs in the country. Today, interactions between MNE R&D personnel and policy makers happen through two channels.

They happen primarily through industry consortia, like NASSCOM and CII (Confederation of Indian Industry). These consortia engage with government officials in order to remove policy and regulatory hurdles in business operations of their members, both MNEs and Indian companies. However, many of our interviewees expressed concern that R&D personnel have limited voice in these interactions. In rare instances, Indian policy makers do seek inputs from MNE R&D personnel in evaluating government-funded R&D proposals or on specific S&T policy issues. But there is a lack of systematic mechanisms to translate technical inputs from these experts into policy design and implementation.

Clearly, R&DCs of many leading MNEs have built diverse linkages with the rest of the Indian innovation system. We also observe that as early-comer R&DCs evolved from SUs or AUs into TCUs or SCUs, their linkages diversified and strengthened. MNE R&DCs' linkages with other companies, including startups are more directly related to MNEs' business activities, as compared to their linkages with HERIs, whereas the linkages with policy makers are the weakest. Furthermore, proportionately few MNE R&DCs in India have TCUs and SCUs and have strong linkages with the Indian innovation system. At the same time, these linkages are limited to only a few top-tier HERIs, a few Indian companies and startups, and rare instances of engagement with policy makers.

5. Discussion

In this section, we first discuss key factors influencing various linkages of MNE R&DCs and then explore lessons and opportunities, particularly for key decision makers, to contribute positively to these linkages. Section 5.1 is based on our interviews and literature survey, whereas Section 5.2 also draws on authors' own experience and understanding with the Indian innovation landscape.

5.1 Key factors influencing linkages

5.1.1 Innovation capabilities in the Indian innovation system

Technology innovation capabilities of HERIs and domestic firms, including startups, and their complementarity to the MNE R&DCs' capabilities are important determinants of linkages between the MNE R&DCs and the rest of the Indian innovation system. This aligns with findings in multiple studies, involving surveys of MNEs, statistical analyses of MNEs' R&D investments and innovation indicators for the host countries, and qualitative studies, that a host country with higher expenditure in domestic R&D and more advanced indigenous innovation capabilities is more attractive to MNE R&D activities and can benefit more from these activities (Cohen and Levinthal 1989) (Fu, Pietrobelli et al. 2011) (Marin and Arza 2009) (Li 2011) (Pietrobelli and Rabellotti 2011). Below, we discuss how the capabilities of specific actors in the Indian innovation system influence their linkages with MNE R&DCs.

Capabilities of HERIs in education and research: A key motivation of MNE R&DCs in building linkages with HERIs is to have early access to students (potential recruits) and to ensure that their curricula and training keep pace with changing needs of the job market in industrial R&D. Most interns at MNE R&DCs are graduate students (who are more qualified to engage in research projects than undergraduate students) from top-tier

Indian HERIs, like IITs and IISc, because these HERIs have an international reputation for their highly selective admissions process and their record of having several graduates who have been incredibly successful in science and technology careers (including research) in the USA and Europe—as the head of an R&DC explained:

> *"One, they are [the] best in the country. Second, they are our hiring pipeline [and] also the place where we have existing personal collaborative initiatives…".*

MNE R&DCs' goals in collaborating with HERIs in research and funding them are:

1. to get access to and promote early-stage industry-relevant research at HERIs that have demonstrated capabilities to produce high-quality research in relevant technology areas.
2. to get access to research infrastructure at the HERIs.

Particularly over the last two decades, a number of Indian HERIs have excelled in many areas of science and engineering research, such as IISc, the seven oldest IITs, ISRO, and a few research institutes under the Council of Scientific and Industrial Research (CSIR). However, most other Indian universities lag drastically behind these top-tier HERIs in research capabilities (many do not engage in research). In the 2018 QS university rankings ("QS University Rankings") only IIT Bombay, IIT Delhi, and IISc ranked among the top 200 HERIs in the world (all three ranked below 170). The relative impact of scientific publications from India is 30% below the world average[14]. Therefore, MNE R&DCs choose to build long-term collaborative relationships only with the top-tier HERIs. The head of a leading MNE R&DC explained:

14 Country rankings based on Category Normalized Citation Impact of scientific publications with country-resident authors in Web of Science and InCites database of Clarivate Analytics (Clarivate Analytics).

> *"When it comes to strategic relationships you want an institute which has a history of… research culture as opposed to pure teaching institutes…".*

Furthermore, as one interviewee emphasized, the research infrastructure at the top-tier HERIs is also an incentive for MNE R&DCs to build strategic relationships with them, because:

> *"…the amount of money that goes into IIT infrastructure and IISc [infrastructure] is just incredible… no multinational can match that... [Centre for Nano Science and Engineering] in IISc [received from the government] ₹ 150 crore (about $23 million)… I mean [no] multinational... will invest so much money in one go."*

For example, research teams at GE's JFW Centre working on advanced materials and jet engine design are interested in getting access to state-of-the-art testing facilities at IITs (IITM 2015-16, p. 344).

However, in many cases the more research-focused (more 'R' than 'D') Indian R&DCs of MNEs prefer collaborating with the top HERIs abroad with stronger demonstrated research capabilities compared to even the top Indian HERIs in relevant technology areas—e.g. MIT, University of California-Berkeley, and Stanford.

A key barrier in MNE R&DC-HERI collaborations in India is the mismatch between expectations of the R&DCs and HERIs. Faculties even at top Indian HERIs have traditionally been disinclined to undertake industry-relevant research. Additionally, with a goal to integrate the research outputs into their products, MNE R&DCs often have strict timelines, whereas academia commonly works with more flexible timelines and goals. Although such mismatch of expectations is observed in university-industry collaborations even in more advanced innovation systems, e.g. in the USA, it is amplified in India by the long-prevailing isolation between industry and academia.

Capabilities of other firms (excluding startups): With which firms MNE R&DCs build linkages through R&D outsourcing, supplier relations, and co-innovation depends largely on the capabilities of those other companies. Over the last three decades, since the economic liberalization in India, Indian firms have built global competitiveness in a few industry sectors. Indian IT services firms exemplify how firms from a developing country can move up in global value chains in a dynamic high-tech sector (Lundvall, Joseph et al. 2009) (Lee, Park et al. 2014). The top service-provider firms, like Tata Consultancy Services Ltd. (TCS), have moved up the value chain to also perform part of R&D activities for their client firms. But when MNEs enter a greenfield industry in India, they have to invest in building the capabilities in the local supplier ecosystem.

The demonstrated technological capabilities of the co-innovator firms and their complementarity to the MNE R&DCs' capabilities are the key determinants in selecting the co-innovator firm. Although Indian firms' investment in R&D has always been weak, many large Indian firms are beginning to expand their R&DCs, organize their role and structure, and figure out how to harness their full potential for R&D-led innovation beyond product adaptation. Therefore, MNEs are co-innovating with some of these firms which have demonstrated their technological capabilities, built through recently increased R&D efforts.

Capabilities of startups: While MNEs aim to explore new market opportunities and technology segments through startup engagement, involvement of their R&DCs is required to mentor startups only if the startups are innovating close to the technological frontier or can potentially add value to a broad set of product lines or technologies of the MNEs. In other cases, product development divisions of MNEs have sufficient expertise, if at all necessary, to support the startups' innovation efforts. However, partly because the Indian startup ecosystem is quite young, most Indian startups focus only on adapting technologies, such as Internet and mobile applications that are already implemented elsewhere in the world to provide services like e-shopping, digital payments, and social media. Therefore, engagement with such startups is typically not a good fit in the R&D strategy of MNE R&DCs. R&D-led entrepreneurial spin-offs are quite rare in

India, although the number of startups originating from incubators and accelerators at top HERIs like IISc and IITs is growing in recent years[15].

Additionally, a typical startup focuses on addressing a niche problem and has a short timeline to get its product into the market and scale up. Therefore, if MNE R&DCs have a longer-term strategy to explore how to integrate the startup's technology into their product lines or technology platform, this mismatch between expectations of the R&DCs and startups is a key challenge in the success of the R&DC-startup collaborations. However, such mismatch is not uncommon even in more mature startup ecosystems in developed countries.

5.1.2 **Organizational structure of MNEs**

The R&DCs look at their internship programs not only as a way to train potential recruits, but also as an opportunity to increase their own throughput in developing, testing, and prototyping early-stage research ideas, for which they otherwise might not have enough human resources.

MNE R&DCs' propensity to build external linkages mainly depends on the nature of their R&D activities. For example, "centers of excellence" of MNEs, which engage in long-term exploratory research (similar to academic research)—for example, Microsoft Research India and Texas Instrument's Kilby Labs India—are more likely to collaborate with HERIs. Similarly, as compared to R&DCs that are directed by other R&DCs, R&DCs with autonomy to plan and budget their R&D are more likely to build external linkages. This autonomy gives them the flexibility to make decisions related to providing funding for research in HERIs, for co-innovation projects, and for startup mentorship programs.

Furthermore, R&DCs that also seek R&D funding from outside their parent MNEs consider external research collaborations necessary, particularly with HERIs, to build their own reputation as a center of excellence

15 The Silicon Valley startup ecosystem grew with the support of technology product companies and of research universities like Stanford. Similarly, the Boston startup ecosystem flourished in a large part due to the presence of MIT and Harvard.

within the local and global research community, so as to increase prospects of getting external research funding.

Due to the organizational structure of MNEs' Indian subsidiaries, their R&DCs typically are not part of interactions between the MNEs and Indian policy makers. Based on experiences of multiple interviewees, generally sales and marketing representatives of MNEs interact with Indian policy makers, even on technology policy issues. They primarily focus on convincing the government to procure their products without being able to provide sound technical advice.

5.1.3 **Institutional context in India**

Ease of doing business in the startup ecosystem: When financial regulations in the country are favorable to startups, foreign direct investments from MNEs into the startup ecosystem are incentivized. Key regulatory characteristics that are especially important for startups include, among others, the ease to "exit" startups (i.e. to sell the ownership stake in the startup to get return on investment) and the tax rebates on investments in and revenue from startups (young and small-scale enterprises). For a long time, the growth of entrepreneurship in India was impeded by the complexity of, and difficulty in, obtaining necessary licenses and permits from local, state, and central governments, as well as the lack of investment and credit opportunities for startups (Dutta, Lanvin et al. 2015). In 2018, India ranked 100th on the World Bank's 'Ease of Doing Business' index, behind USA (6th), UK (7th), Israel (54th), and China (78th) (World Bank 2018). However, with continued exponential growth over the last few years, India now has the 3rd largest technology startup ecosystem in the world (NASSCOM 2018). The Indian government has recently launched targeted national initiatives to promote entrepreneurship, which provide (i) funding for incubators which bring together investors, industry mentors, and startups, and (ii) credit guarantee and tax breaks for technology startups (Government of India 2016). MNEs' investments in Indian startups are, therefore, growing—two out of every five active startup investors in India are foreign investors, including venture capital subsidiaries of foreign MNEs (NASSCOM 2017).

Nature of policy making processes: In interactions between MNE researchers and the Indian policy makers, including their interactions through industry consortia, the most challenging barrier is the low perceived legitimacy of MNE R&D personnel among Indian government officials. In the words of a senior researcher at an MNE R&DC:

> *"…they [policy makers and academics serving on government-convened technical panels] always think that [MNE R&D people] come as venders, … that [MNE people] go there only to make money for [their company], which is not true… for technologists"*

This low perceived legitimacy stems from the policy makers' experience of interacting with the sales and marketing representatives, who are sent by the MNEs to engage with policy makers also on technology policy issues. MNE R&DCs' interactions with the policy makers are further weakened due to the absence of systematic mechanisms and initiative by the policy makers to seek and incorporate technical advice in policy-making and implementation.

Absence of active technical forums: In more advanced innovation systems like the US, technical forums that connect researchers from different parts of the innovation system act as a bridge between technical experts and policy makers on issues related to technology policies. These issues include technical standards, technology roadmaps for the country, and IP-protection laws. In India, however, there are few active technical forums and they also struggle to find a sustainable funding model to support their activities.

5.1.4 **Networks and geographical proximity**

Networks of individual researchers and their mobility (e.g. from academia to industry) also play a role in initiating and strengthening linkages. For example, alumni of HERIs now working at MNE R&DCs play a key role in effecting R&DC-HERI research collaborations. Because geographical proximity between R&DCs and other actors in the innovation system facilitates such interactions, IISc has been able to build denser linkages with MNE R&DCs in Bengaluru (IISc 2015-16b, IISc 2015-16a), as compared to distant HERIs.

To summarize this subsection, we find that the nature of the R&D activities of MNE R&DCs and the level of autonomy they have to plan and execute their R&D are key determinants of whether the R&DCs build external linkages and also of the nature of these linkages. Therefore, although there are hundreds of MNE R&DCs in India, proportionately only few R&DCs, which have such autonomy have built strong linkages. Furthermore, we find that MNE R&DCs in India have built strong linkages with only a few Indian HERIs and Indian companies including startups that have demonstrated strong innovation capabilities. We also find that the low perceived legitimacy of MNE R&D personnel among the policy makers and the absence of systematic mechanisms to seek and incorporate technical advice in making and implementing policies are major barriers in engagement between MNE R&DCs and the Indian policy makers.

5.2 **Lessons and opportunities**

Here we discuss four areas in which policy interventions can be most impactful to strengthen and scale up existing linkages between MNE R&DCs and the rest of the Indian innovation system and to facilitate new mutually beneficial linkages.

5.2.1 **Engagement between MNE R&DCs and HERIs**

Advancing training of students and young researchers through MNE R&DCs: Development of human capital, especially future and early-career researchers, is of utmost importance for an emerging economy and rising knowledge power like India in order to harness its demographic dividend. Many MNE R&DCs in India significantly contribute to training and career development of students and young researchers, through their internship programs and in-house postdoctoral positions. Graduate student internships at MNE R&DCs is an important linkage not only for the expansion of skill development of research personnel in India but also for promoting and deepening research collaborations between HERIs and MNE R&DCs.

There is potential to scale up these linkages by expanding the internship opportunities for graduate students, in particular, and establishing joint-supervision PhD programs (similar to the "External Registration Programme" for PhD of IISc (IISc 2015-16b, p. 246)) and postdoctoral appointments shared between MNE R&DCs and HERIs. In addition to the MNE R&DCs, these positions could be supported also by the DST, Department of Biotechnology (DBT), other R&D-funding agencies, HERIs, as well as philanthropy. The Prime Minister's Fellowship Scheme for Doctoral Research, which shares half of the cost of PhD students performing research in industrial R&DCs (Dutta, Lanvin et al. 2015, p. 128) is a useful model for such a program.

Short-term positions at industrial R&DCs, especially MNE R&DCs (because they are likely closer to the technical frontier), help graduate students and postdoctoral researchers hone industry-relevant skills. Given that only a fifth of Indian engineering graduates are considered employable in industry (Aspiring Minds 2011) (Aspiring Minds 2014), and that industrial R&DCs are among primary employers of science and engineering PhDs, working with the industry (including MNE R&DCs) to expand short-term positions and long-term employment opportunities for PhDs and postdocs needs to be a major component in the future roadmap of Indian HERIs and an integral part of government initiatives for skill development and for the expansion of R&D funding and doctoral programs in the country.

Given that India's researcher pool is expanding rapidly (it almost doubled during 2005—2015 (UNESCO Statistics)), and that Indian R&DCs of US MNEs contribute to more US patents than the MNEs' R&DCs in any country except the USA (Kamat, Sagar et al. 2019), MNEs can benefit greatly by continuing to expand their R&D base in India, by recruiting researchers in long-time positions as well as short-term internships and postdoctoral positions. Recruiting PhDs from Indian HERIs could also help MNE

R&DCs expand and deepen their research collaborations with HERIs (refer to discussion of MNE R&DCs' internship programs in Supplementary Material).

Expanding research collaborations between MNE R&DCs and HERIs: Research collaborations between industry and academia play a crucial role in improving capabilities across the innovation system by promoting industry-relevant research at HERIs and long-term exploratory research in industry and can help accelerate the overall pace of innovation by facilitating commercialization of academic research (Etzkowitz and Leydesdorff 2000, 2005, pp. 209-239). For an emerging economy like India, research collaborations between its HERIs and R&DCs of MNEs from developed countries are one of the most impactful types of linkages, because they can significantly enhance spillovers to the Indian innovation system in the form of technical know-how and overall research culture (Reddy 2005).

There is immense potential in India to deepen such R&D collaborations. Establishing R&D wings of MNEs on campuses of the top Indian HERIs is one way to underpin long-term strategic relationships between the HERIs and the MNE R&DCs. Trilateral collaborations between Indian HERIs, MNE R&DCs, and top HERIs in MNE's home countries could further enhance returns of collaborations for Indian HERIs in form of research outputs and knowledge exchange. Building and strengthening such linkages, therefore, needs to be an integral part of the strategy of both—of MNE R&DCs as they progress to take up more high-end R&D activities, and of Indian HERIs as they aspire to be globally competitive HERIs. Organizations like Indo-US Science and Technology Forum (IUSSTF) could act as a conduit to support such cross-border collaborations and strategic relationships.

Funding support from the government for HERI-MNE R&DC research collaborations is an effective strategy to expand such collaborations and also motivate MNE R&DCs to expand their India-relevant frontier R&D activities. However, R&DCs of MNE subsidiaries having majority foreign ownership are not eligible for Indian government's industrial R&D grants. This is a missed opportunity, as illustrated by the following quote from a research group leader at a leading MNE R&DC:

> *"... [R&D funding] schemes [for which MNE R&DCs are eligible]... don't exist (in India) ... So, we look for [research] problems elsewhere (outside India) ...*
>
> *...the ability of having either special projects [or] programs (with funding support from the government) ... would allow a greater degree of investment to come in [also from the industry]."*

If India is to fully benefit from government-funded industrial R&D, then the R&DCs should be evaluated on the basis of their research and innovation capabilities, and not excluded from the grants only because of their foreign ownership. Indian government's 'IMPRINT India'[16] program is a step in the right direction, but has not been very successful as many ministries did not release the funding they committed for the program (Vishnoi 2016). Creative, sustainable, and scalable funding models are therefore needed to promote MNE R&DC-HERI R&D collaborations. Designing such models would require active engagement among MNE R&DCs, HERIs, and the R&D-funding agencies. Given that demonstrated R&D capabilities of HERIs are a key determinant of MNE R&DC-HERI linkages, public R&D funding to HERIs is necessary to first enhance their capabilities, before HERIs are capable to raise a large portion of R&D funding from the industry.

5.2.2 **Engagement between MNE R&DCs and other firms (mature firms and startups)**

Strengthening linkages between MNE R&DCs and other firms (excluding startups): As demonstrated by examples of co-innovation by R&DCs of MNEs and Indian firms, both MNEs and Indian firms can benefit from cooperation at the R&D level. While MNEs are typically closer to the technological frontier, Indian firms have a better understanding of the Indian market. Similar to trilateral collaborations among MNEs and Indian and top foreign HERIs, discussed above, trilateral and quadrilateral research

16 Refer http://imprint-india.org/ (accessed in August 2019). The IMPRINT program focuses on IISc and IITs and requires them to have an industry collaborator on the proposal to be eligible for grants. The industry collaborator is to provide at least 25% of the budgeted support for the research project, in funding or in kind; the government provides the remaining 75% funding to the HERI.

collaborations among MNEs, Indian firms, and Indian and foreign HERIs could also enhance the returns on R&D investments for both MNEs and Indian firms. In addition to MNEs and Indian firms, Indian policy makers and HERIs can play a key role to promote such multilateral collaboration through collaborative R&D grants.

Deepening engagement between MNE R&DCs and technology startups: In order to nurture startup unicorns that could become globally competitive technology firms, the Indian technology startup ecosystem needs many more startups developing R&D-led innovations and applying cutting-edge technologies in a novel way. Technical expertise and resources of leading MNE R&DCs could act as a stimulus and resource for such startups. Because Indian market is not as deeply locked into many incumbent technologies as many developed countries, there is enormous potential for MNEs to explore market opportunities in India through greater R&DC-startup engagement in emerging technology areas, such as electric cars, new forms of urban mobility systems, and the internet of things. Through collaboration with MNE R&DCs, Indian HERIs could also accelerate the success of their startup incubators and become a major source of R&D-led entrepreneurial spin-offs. Incubators at IIT Bombay and IIT Kanpur have had some examples of entrepreneurial spin-offs raising funds from MNEs (IITB 2015-16, p. 32, IITK 2015-16, p. 92).

To these ends, Indian policy makers could engage with HERIs, MNEs, and their R&DCs to promote MNE R&DCs' engagement with startups, including spin-offs by MNE researchers, through the government's "Start up India, Stand up India" program (Government of India 2016).

5.2.3 **Engagement between MNE R&DCs and policy makers**

Most research managers and R&DC heads at leading MNE R&DCs in India have research experience in more advanced innovation systems like the US. Moreover, these R&DCs typically pursue more frontier research than most Indian companies. Therefore, technical expertise at MNE R&DCs would be a valuable input in: (i) government initiatives with strong technical component (e.g. “Smart Cities”, “Make in India”, “Digital India”), (ii) shaping policies and technical standards in emerging technology areas (e.g. big data, renewable energy), and (iii) shaping strategic priorities for R&D-funding agencies such as DST.

Given the challenges in MNE R&DCs’ interactions with Indian policy makers discussed in the previous subsection, strengthening their engagement would require deliberate efforts by both MNEs and policy makers. For example, when engaging with MNEs on issues that need technical expertise, policy makers could insist to interact with MNE researchers and not representatives from non-technical divisions such as sales or marketing. HERIs could also play an important role here by providing ‘neutral spaces’ for engagement on issues pertaining to technology, industrial, and innovation policy including questions relating to emerging technologies. Furthermore, in order to improve the perceived legitimacy of MNE R&D personnel among Indian policy makers, MNEs need to actively enable such deeper engagement of their R&D personnel with the policy makers.

To summarize this subsection, while clearly there is enormous potential to strengthen, replicate, and scale up existing linkages, facilitate new ones, and foster long-term relationships between MNE R&DCs and other actors in the Indian innovation system, harnessing this potential would require systematic efforts by multiple actors and even a shift in the overall research and innovation culture and mindset among key actors. In the case of Indian HERIs, it means paying greater attention to and having a systematic effort for engaging with industry, including MNE R&DCs. In the case of MNEs, it means paying greater attention to building linkages with the Indian innovation system. And, most importantly, for policy makers and R&D funding agencies such as DST, it means (i) understanding the potential value of MNE R&DCs, which requires developing a better understanding of MNE R&DCs’ research and innovation activities, (ii) including MNE R&DCs in regular systematic surveys tracking national R&D activities, (iii) actively supporting stronger collaborations between HERIs and industry, and (iv) taking initiative to deepen their own engagement with technical experts and researchers in industry.

6. Conclusion

Over the last two decades, major emerging economies of India and China are rising as new knowledge powers, by intensifying efforts to enhance their technology innovation capabilities. During the same period, MNEs from developed countries have expanded their R&D activities to developing countries, mainly India and China. In this work, focusing on the case of India, we explore the ways in which presence and activities of MNE R&DCs influence technology innovation capabilities in the Indian innovation system. The Indian case demonstrates that MNE R&DC activities can significantly contribute to the advancement of the technology innovation system in the host developing country through various linkages. Specifically, MNE R&DCs in India have been a major conduit for brain circulation, as they are more successful than R&DCs of Indian firms at attracting Indian and foreign researchers from more advanced innovation systems abroad to India. Moreover, external linkages of MNE R&DCs are contributing to training and career development of students and young researchers and also serve as sources of funding, knowledge, technology, and cultural spillovers

Although these linkages are deepening in the recent years, there is tremendous underutilized potential for the MNE R&DCs and the rest of the Indian innovation system to build, strengthen, and scale up mutually beneficial linkages. And, there are opportunities for policy makers, HERI administrators, and also MNEs to harness this potential by supporting stronger and more diverse linkages embedded in long-term strategic relationships. Such linkages could help foster the expansion of research capabilities of HERIs as well as the growth of technology startup ecosystem and industrial R&D in India. Technical expertise at MNE R&DCs could be a valuable input to policy discourse, policy-making processes and government initiatives aimed at promoting science, technology and innovation capabilities in the country. Furthermore, with a rapidly growing Indian innovation system and with innovation-driven development high up on the government agenda, MNEs could also benefit by expanding their high-end R&D activities in India.

Through this study, we have developed an in-depth qualitative understanding of the dynamics of MNE R&DCs' linkages. India's case demonstrates that strong linkages between MNE R&DCs and rest of the innovation system in host developing countries can be instrumental in enhancing the innovation capabilities of the latter. However, deepening these linkages and extracting their benefits require systematic and collaborative efforts by multiple actors, including policy makers and HERI administrators in the host countries and also MNE R&DCs. This understanding also provides a foundation for future research on MNE R&D landscape in India (and possibly other developing countries). Particularly promising directions for future research would be a quantitative study of the nature of MNE R&D activities in India—low-end vs high-end R&D activities—along with their comparison with innovation activities in rest of the Indian innovation system and potentially, also with MNE R&D landscape in other countries like China.

A. Interview Process

A.1 Details of interviews

Organization	Category	Industry (not applicable to universities)	"Home"/ headquarters country
Scoping interviews (phone/video call): These interviews were conducted between November 24th, 2015 and July 1st, 2016.			
Xerox Research Center India	MNE R&DC	Software, IT, and computer hardware	US
Intel India	MNE	Software, IT, and computer hardware	US
Microsoft Research India	MNE R&DC	Software, IT, and computer hardware	US
Boston Scientific India	MNE	Software, IT, and computer hardware	US
DuPont India	MNE	Multiple industries including chemicals and agricultural technology	US
Hewlett-Packard (HP) India	MNE R&DC	Software, IT, and computer hardware	US
International Business Machines (IBM) Research India	MNE R&DC	Software, IT, and computer hardware	US
Texas Instruments (TI) India	MNE R&DC	Software, IT, and computer hardware	US
Tata Consultancy Services (TCS)	Indian company	Software, IT, and computer hardware	India
Tata Sons	Indian company (conglomerate)	Multiple industries including software and IT, automobiles, and chemicals	India
Indian Institute of Science (IISc), Bengaluru	Indian HERI	N.A.	India
Indian Institute of Technology, Delhi	Indian HERI	N.A.	India
Harvard University, Cambridge, USA	USA HERI	N.A.	US
US-India Business Council, USA	Industry Consortium	Multiple industries	US

Organization	Category	Industry (not applicable to universities)	"Home"/ headquarters country
Cloud Computing Innovation Council of India	Technology Forum	Software, IT, and computer hardware	India
Detailed in-person interviews: These interviews were conducted between July 7th and July 15th, 2016.			
John F. Welch Center, General Electric, Bengaluru	MNE R&DC	Multiple industries including healthcare technology and aviation equipment	US
IBM Research India, Bengaluru	MNE R&DC	Software, IT, and computer hardware	US
Texas Instruments, Bengaluru	MNE + its R&DC	Software, IT, and computer hardware	US
Xerox Research Center India, Bengaluru	MNE R&DC	Software, IT, and computer hardware	US
Microsoft Research India, Bengaluru	MNE R&DC	Software, IT, and computer hardware	US
HP India	MNE R&DC	Software, IT, and computer hardware	US
TCS Innovation Lab, Bengaluru	Indian Company's R&DC	Software, IT, and computer hardware	India
Robert Bosch Center for Cyber-Physical Systems, IISc, Bengaluru	Indian HERI	N.A.	India
IIT Delhi	Indian HERI	N.A.	India
Cloud Computing Innovation Council of India, Bengaluru	Technology Forum	Software, IT, and computer hardware	India
Phone interview			
Google	MNE	Software, IT, and computer hardware	US

Supplementary Table 1:

Organizations covered in scoping interviews and detailed interviews.

A.2 **Details of interviewees**

	Scoping interviews	Detailed interviews
Job positions of interviewees	1. directors and researchers of MNE R&D centers in India and the US, 2. managers in non-R&D center units of MNEs, 3. research managers, business managers, and top executives in Indian companies, 4. academics in top-tier Indian universities, 5. leaders in industrial consortium and technical forum in India and the US	1. 11 directors and researchers at MNE R&D centers in India and at an R&D center of an Indian company, most of who also had previous experience in the USA or the UK, 2. 1 vice-president of a technical forum in India, who also had previous experience of leading research teams and R&D centers in India of three MNEs, 3. 2 academics, one each from two top-tier Indian universities, 4. 1 former government relations manager of an MNE in India, 5. 1 relationship manager in an MNE R&D center.
Organizations of interviewees	6 MNE R&D centers, 3 Indian companies, 3 non-R&D units of MNEs in India, 2 top-tier Indian universities, 1 industrial consortium with operations in the USA and India, and 1 technical forum in India	6 MNE R&D centers, 1 R&D center of an Indian company, 1 non-R&D unit of an MNE in India, 2 top-tier Indian universities, and 1 technical consortium.
Industry sectors of the companies covered	Of the 9 MNE R&D centers and 2 Indian companies, 7 MNE R&D centers and 1 Indian company are in software, IT, computer hardware, semiconductors, and telecommunication technology sectors, while 2 MNE R&D centers are involved in multiple industry sectors which include chemicals, healthcare technology, and aviation equipment.	Of 5 MNE R&D centers, 1 non-R&D unit of an MNE and 1 R&D center of an Indian company are in software, IT, computer hardware, semiconductors, and telecommunication technology sectors, while 1 MNE R&D center is involved in multiple industry sectors which include chemicals, healthcare technology, and aviation equipment.

Supplementary Table 2

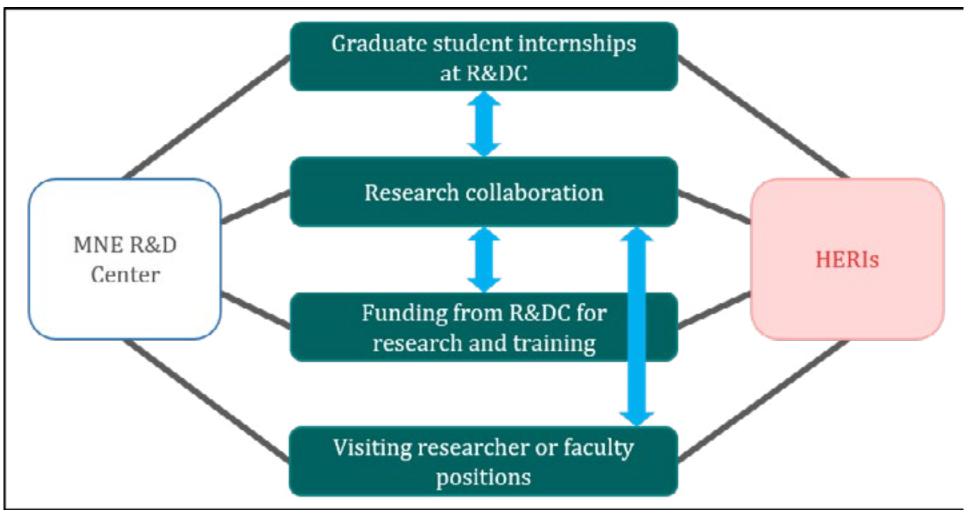
Details of interviewees.

B. Linkages of MNE R&D Centers in India

In this section we present our analysis of the dynamics of various interactions and linkages between MNE R&DCs in India and other actors in the Indian IS. We focus on those linkages which have important policy implications in the short term, and which are insightful mainly for policy makers, R&D funding agencies, and HERI administrators.

B.1 Linkages with HERIs

Interactions with HERIs are important for MNE R&DCs primarily to get early access to students (potential recruits) and to ensure that their university curricula and training keep pace with changing needs of the job market in industrial R&D.



Supplementary Figure 1
Linkages between leading MNE R&DCs and top Indian HERIs, and interplay among the linkages (indicated by two-headed solid arrows).

We discuss three most interesting types of linkages between MNE R&DCs and HERIs.

B.1.1 **Short-term positions for students and young researchers**

The growth of MNE R&DCs in India has opened more opportunities for students, especially in engineering, to get exposed to cutting-edge industrial R&D, through internships at the R&DCs within India, instead of having to seek such opportunities abroad. The R&DCs look at their internship programs not only as a way to train potential recruits, but also as an opportunity to increase their own throughput in developing, testing and prototyping early-stage research ideas, for which they otherwise might not have enough human resources. Most of the PhD student interns are from IISc or the 7 oldest IITs—HERIs which have a reputation for high-quality education and research programs.

Graduate student internships at MNE R&DCs is, thus, an important linkage not only for the expansion of skill development of research personnel in India but also for promoting and deepening research collaborations between HERIs and MNE R&DCs.

B.1.2 **Research collaborations and funding**

Research collaborations between industry and academia play a crucial role in improving capabilities across the innovation system, accelerating the pace of innovation (Etzkowitz and Leydesdorff 2000, 2005, pp. 209-239). Research collaborations between R&DCs of MNEs from developed countries and domestic HERIs could, therefore, significantly enhance spillovers, in the form of technical know-how and overall research culture, from the R&DCs to the host innovation system (Reddy 2005).

Research collaborations of MNE R&DCs with Indian HERIs have been growing in recent years—mostly with IISc and IITs (IISc 2015-16a) (IITB 2015-16) (IITD 2015-16) (IITK 2015-16) (IITKgp 2015-16) (IITM 2015-16), and with a few research groups at the National Institutes of Technologies (NITs) or Indian Institutes of Information Technology (IIITs). These collaborations are typically aimed at research papers, and not at patents, mainly due to the difficulty in negotiating agreeable intellectual property (IP)-sharing terms. In case of a patentable research output, the R&DC and HERI sign a Memorandum of Understanding (MOU) and a contractual agreement for sharing the IP (IITM 2015-16).

MNE R&DCs' goals in collaborating with HERIs are mainly:

1. to get access to and promote early-stage industry-relevant research in their technical domain at HERIs;
2. to get access to research infrastructure at the HERIs –for example, research teams at GE's JFW Centre[17] working on advanced materials and jet engine design are interested in getting access to state-of-the-art testing facilities at IITs (IITM 2015-16, p. 344);

MNE R&DCs that seek external funding in addition to internal R&D funding from the MNE, also seek to collaborate with universities to demonstrate their own capabilities in exploratory technical research, as this helps the R&DCs (i) build their reputation as a center of excellence among the local and global research community, and (ii) increase prospects of getting external research funding if needed.

However, in many cases the Indian "centers of excellence" of MNEs often prefer collaborating with the top HERIs abroad which typically have stronger demonstrated research capabilities in relevant technology areas—e.g. MIT, University of California-Berkeley, and Stanford—compared to Indian HERIs.

Research funding. MNE R&DCs choose to collaborate with or fund those research groups and HERIs which have demonstrated capabilities to produce high-quality research in relevant technology areas. However, faculties even at top Indian HERIs have traditionally been disinclined to undertake industry-relevant research. Additionally, MNE R&DCs often have strict timelines and intend to integrate the research outputs into their products, whereas academia commonly works with more flexible timelines and goals. Although such mismatch of expectations is observed in university-industry

17 John F. Welch Centre (JFWC), Bengaluru is General Electric's main umbrella of R&D division in India. There are multiple centers focusing on different technology domains, often working independently under the JFWC.

collaborations even in more advanced innovation systems, e.g. in the USA, it is amplified in India by the long-prevailing isolation between industry and academia.

Indian government's support to encourage HERI-MNE R&DC research collaborations is unfortunately weak. While R&DCs of Indian companies (having majority Indian ownership) are eligible to apply for numerous research grants from the Indian government, MNE R&DCs (with minority Indian ownership in MNE subsidiary) are not eligible for these grants. This is a missed opportunity. There are even examples of MNE R&DCs in India leading major research projects funded by governments abroad. Indian government's 'IMPRINT India' program is a step in the right direction to encourage HERI to collaborate with industry including MNE R&DCs, but did not been very successful as many ministries have not released their committed funding for the program (Vishnoi 2016).

B.1.3 **Visiting or adjunct positions for MNE researchers and HERI faculty**

Mobility of researchers is an important channel for diffusion of knowledge, especially tacit knowledge (Li 2011), across the innovation system. Because faculties at the top Indian HERIs have flexibility to design their course curricula, visiting teaching/research positions at these institutes are appealing to MNE researchers and are easier to arrange as compared to other universities and colleges. The main motivation behind these initiatives is building relationships with the HERIs in order to (i) facilitate future collaborations and (ii) get access to their research infrastructure.

The aforementioned linkages between MNE R&DCs and HERIs are interrelated. Connections among individual researchers, their informal interactions and mobility of researchers play a very important role in initiating and strengthening research collaborations, e.g. alumni of HERIs now working at MNE R&DCs effecting R&DC-HERI research collaborations. Often visiting faculty positions and sometimes internship positions, too, emerge out of informal interactions and connections between individual researchers. Geographical proximity between R&DCs and HERIs also helps catalyze such interactions—this has helped IISc build denser linkages with MNE R&DCs in Bengaluru (IISc 2015-16b, IISc 2015-16a), as compared to distant HERIs.

Linkages between MNE R&DCs and HERIs		
Types of linkages	**Outcomes and implications**	**Key factors influencing linkages**
Internships	Improvement in training and employability of students Increased R&D throughput of MNE R&DCs Increased propensity of research collaborations between intern's thesis advisors at HERIs and internship mentors at R&DCs	Educational qualifications of interns—PhD students more likely to engage in advanced research Reputation of graduates from the HERIs—most graduate student interns from IISc and IITs **
Research collaborations and funding	Increased propensity of industry-relevant research at HERIs Spillover in the form of knowledge and technical know-how to HERIs More funding for HERIs Reputation of R&DCs as centers of excellence	Demonstrated research capabilities and reputation of the HERI researchers ** Availability of state-of-the-art research infrastructure at the HERIs ** Informal interactions among researchers at MNE R&DCs and HERIs ** Funding model of MNE R&D—R&DCs collaborate more, if they need to improve prospects of getting external R&D funding
Exchange of researchers/ faculty on visiting positions	Improvement in education, training and, in turn, employability of students Facilitation of research collaboration between HERI and R&DC Career development of visiting researchers from HERIs through exposure to industrial R&D and, in turn, higher propensity of industry-relevant research at the HERIs	Geographical proximity ** Flexibility for visiting faculty in designing courses ** Demonstrated capabilities and reputation of HERI researchers **

Supplementary Table 3

Key takeaways about linkages between MNE R&DCs and HERIs in India.

**These factors positively influence the respective linkages.

B.2 Linkages within Industry (with other companies in India, including MNEs)

Inter-firm linkages play a crucial role in advancing technology innovation, especially for developing countries as their domestic firms increasingly interact with MNEs from developed countries through Global Value Chains (GVC) and with their R&DCs through Global Innovation Networks (Pietrobelli and Rabellotti 2011, 2017).

B.2.1 R&D outsourcing and supplier capabilities building

Many MNEs outsource part of R&D—generally low-end—to other firms in India, i.e. they use other firms as Supporting or Assignment Units. MNEs' R&DCs manages the R&D segmentation (to outsource a particular segment) and, later, integration of its outcomes. This helps the R&D-service provider firms upgrade their technical capabilities, which typically follow, and hence lag, innovation capabilities of their clients.

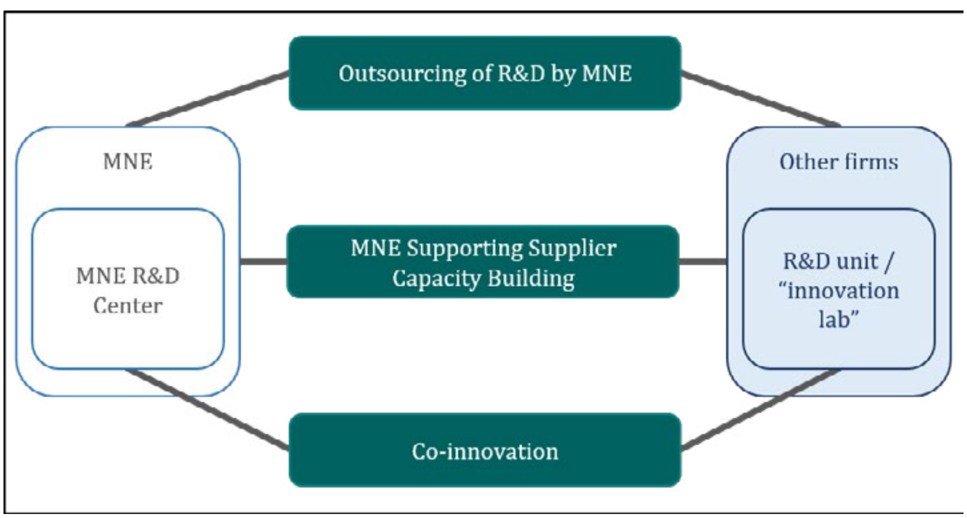
MNEs that entered a greenfield industry sector in India and needed to use local supplier ecosystem, have had to help local supplier ecosystem develop its capabilities. While the relationships with the supplier firms are managed by a business unit of the MNEs, their R&DCs often provide the technical resources and mentoring to the supplier firms. Availability of supplier firms with upgraded technical capabilities, in turn, also benefits other firms in the same industry sector as the MNE.

B.2.2 Co-innovation

In recent years, firms with complementary technology innovation capabilities have begun collaborating with each other right from the R&D stage—a trend called "co-innovation". There are two main reasons behind the emergence of this trend. First, increasing technological complexity, segmentation of GVCs, and shrinking R&D-to-product timeline require integration of knowledge from different sources from the R&D stage. Second, because R&D units in firms are more agile than other product development and production units to keep up with rapidly emerging technologies, R&DCs from two different firms sometime collaborate on joint product development in emerging technology areas.

The trend of co-innovation is also growing in India, where MNE R&DCs collaborate with their counterparts in Indian companies and other foreign MNEs within India or abroad. An example of a successful co-innovation is a wireless charging technology for electric cars that GE's JFWC developed in collaboration with Mahindra Reva[18]. Based on our interviews, co-innovation in India is growing trend, but its other examples are not publicly disclosed.

Co-innovation with MNE R&DCs from more advanced developed countries helps firms in the host developing country climb up in their GVCs and increase technical sophistication of their products (Reddy 2005). However, the domestic firms fully benefit only when building capabilities for independent—not only client-dependent—frontier R&D is part of their corporate strategy.



Supplementary Figure 2

Linkages between leading MNE R&DCs and other companies in India.

18 "*GE reveals wireless charging for electric vehicles*", https://shifting-gears.com/ge-reveals-wireless-charging-for-electric-vehicles/, Feb. 6, 2016, accessed August 12, 2019. We learned through an interview that wireless charging of electric cars is sensitive to the alignment between the car and the charger, making it less convenient, while the technology developed by GE and Mahindra Reva does not require such an alignment.

Linkages between MNE R&DCs with other companies in India		
Types of linkages	**Outcomes and implications**	**Key factors influencing linkages**
Outsourcing of R&D by MNEs	Enhanced innovation capabilities of R&D-service providers	Demonstrated capabilities of R&D-service provider ** Cost effectiveness of outsourcing ** Global and local trends in industry sector vis-à-vis R&D segmentation
Support from MNE R&DCs to build supplier capacity	Enhanced technical capabilities of suppliers (also available to other companies in industry sector) Integration of suppliers in Global Value Chains and Global Innovation Networks	Cost-effectiveness for MNE to use local suppliers ** Indigenous capabilities of local supplier ecosystem **
Co-innovation	Technically more sophisticated products for Indian market, which can potentially appeal also to global markets Increased propensity of innovation across industry sector in India, also, through competition	Proclivity of collaborating firms for R&D and their demonstrated capabilities **

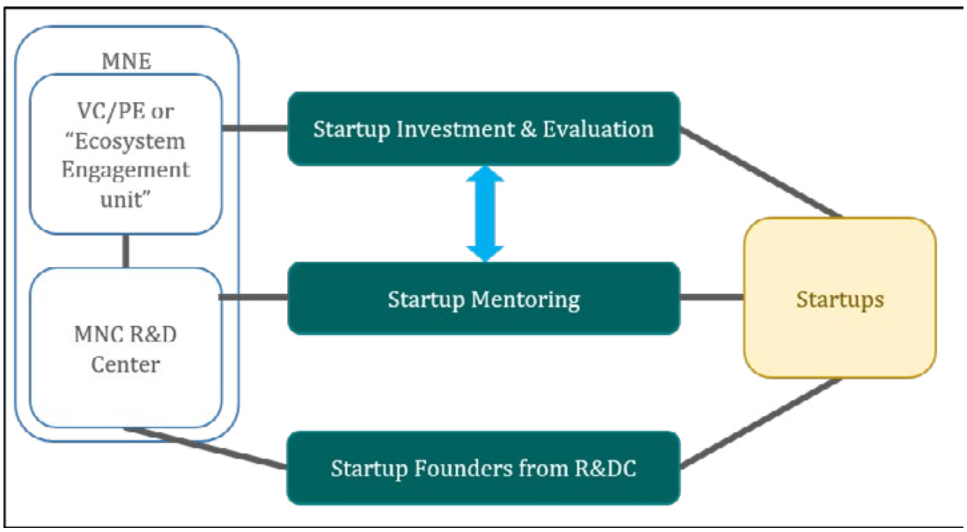
Supplementary Table 4

Key takeaways about linkages between MNE R&DCs and other companies in India. **These factors positively influence the respective linkages.

B.3 Linkages with the Startup Ecosystem

Globally, MNEs look upon engagement with startups as a cost-effective way to explore opportunities in new markets and new technology segments, to upgrade their products and expand the applicability of their technology platforms. Rapid economic growth in India provides greenfield opportunities in many industries, e.g. growing opportunities in digital technologies due to the rapid expansion of mobile Internet connectivity. MNEs are seeking to tap into such opportunities through startups, and R&DCs of MNEs engage with startups as a part of this strategy.

In India, MNEs or their R&DCs conduct or co-organize innovation competitions. Winner startups receive a monetary prize and an opportunity to work with the MNEs or their R&DCs to develop their technology further. For example, "Google for Entrepreneurs", IBM, Amazon web services, Facebook, and Microsoft Accelerator are sponsors for NASSCOM's multiyear '10,000 startups' initiative (NASSCOM), and Texas Instruments has joined India's Department of Science and Technology (DST) to organize 'India Innovation Challenge.'



Supplementary Figure 3
Linkages between leading MNE R&DCs and technology startups, and interplay among the linkages (indicated by two-headed solid arrows).

There are two models of engagement between MNE R&DCs and Indian technology startups.

B.3.1 **Engagement through Venture Capital (VC) or "Ecosystem Engagement" divisions of MNEs**

In this model, the VC or the "ecosystem engagement"[19] division of the MNE is responsible for leading and managing the startup engagement. The R&DCs are involved in evaluating the startup technology, mentoring startups, and strategizing how their technology can complement and integrate with the MNE's products or technology platform. IBM, Microsoft Ventures Accelerator (Microsoft) and Intel Capital (Intel), for example, have adopted this model and run their own startup accelerators in India. ZoomCar, a car-rental/car-sharing startup, is an example of a success story[20] (Back 2014) from Microsoft's Accelerator in Bengaluru, while Intel Capital is one of high-profile investors in Snapdeal —an Indian startup unicorn ("The Unicorn List 2016" 2016).

B.3.2 **Direct engagement**

In this model the R&DC researchers directly mentor selected startups and give them access to the infrastructure and technology of the R&DC, along with, or sometimes without, financial investment. Xerox Research Center India adopted this model as a part of their strategy to explore India's market for Xerox's IT services business[21].

Some MNEs take a hybrid approach to startup engagement. For example, while Intel Capital pursues the first model for startup engagement, Intel India Maker Lab pursues the second.

There are many challenges which are common in both these models. A typical startup focuses on a niche problem to address and has a short timeline to get its product in the market and scale up. On the other hand, the MNE R&DCs have a longer-term strategy to explore how to integrate the startup's technology into their product lines or technology platform. This mismatch of expectations is not uncommon even in more mature startup

19 "Ecosystem Engagement" divisions are new type of units in firms which have a broad mandate of engaging with various other actors in the innovation system.

20 ZoomCar has raised $115 million to date, according to https://www.crunchbase.com/organization/zoomcar-india#section-overview, accessed on August 13, 2019.

21 After our interviews, Xerox separated its services business as a separate spin off company Conduit, Inc in December 2016. Xerox Research Center India was supposed to be absorbed into Conduit, Inc.

ecosystems in developed countries. A young startup ecosystem in a developing country like India faces additional challenges, nonetheless. Most Indian startups focus only on adapting technologies that are already implemented elsewhere in the world. Therefore, engagement with such startups is typically not a good fit in the R&D strategy of MNE R&DCs.

In addition to these linkages, many MNE researchers are also founding their own startups in India—one example is Ola Cabs, an Indian startup unicorn in transportation network business, co-founded by Bhavish Aggarwal who was previously a researcher at Microsoft Research India. There are also examples of entrepreneurial spin-offs from MNE R&DCs. For example, Digital Green which began as a project of Microsoft Research India and was later spun off into a non-profit startup working to empower "smallholder farmers to lift themselves out of poverty by harnessing the collective power of technology and grassroots-level partnerships"[22].

Linkages between MNE R&DCs and Indian technology startups		
Types of linkages	**Outcomes and implications**	**Key factors influencing linkages**
Through VC/PE or ecosystem engagement (EE) divisions (indirect model)	Increased availability of technical and financial resources for startups Enhancement of technical capabilities of startups Expansion of market opportunities and of applicability of technology platforms of MNE Promotion of entrepreneurship across startup ecosystem	Relative positions of VC/PE or EE division and R&DC in India in organizational structure of MNE Complementarity of VC/PE startup investment strategy and technical specialization of R&DC ** Ease of business in startup ecosystem **
Direct mentorship	(All listed for the 'indirect' model and...) Promotion of R&D-led entrepreneurial innovations Exploration of market opportunities by MNE, with low financial investment	Technical sophistication of the startup technology **

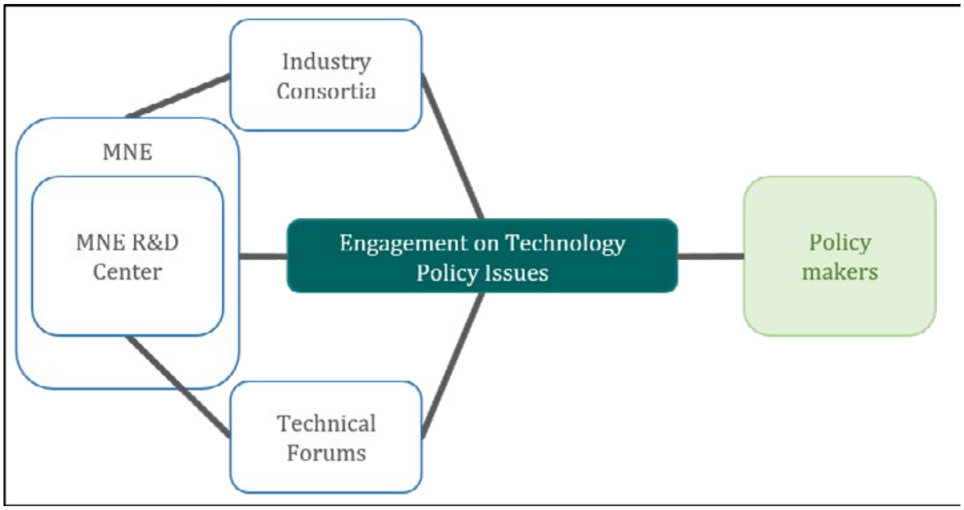
Supplementary Table 5

Key takeaways about linkages between MNE R&DCs and tech startups in India. **These factors positively influence the respective linkages.

22 Refer to the website of Digital Green, https://www.digitalgreen.org/about-us/, accessed August 13, 2019.

B.4 **Linkages with Indian Policy Makers**

Technical expertise is a critical input to designing and implementing science, technology, and innovation policies, including technical standards and industrial policies like IP-protection laws. MNE R&DCs in India are a valuable pool of technical expertise for India.



Supplementary Figure 4
Linkages between leading MNE R&DCs and Indian policy makers.

Interactions between early-comer MNE R&DCs like TI and Indian policy makers played an important role in ensuring policies that enabled and facilitated the expansion of MNE R&DCs in the country. Today, interactions between MNE R&D personnel and policy makers happen mainly in two ways.

B.4.1 **Engagement through industry consortia**

The primary motivation of industry consortia, like NASSCOM[23] and CII[24], in engaging with government officials is to remove policy or regulatory hurdles in business operations of their members—MNEs and Indian companies. Although most of the interaction between MNE R&D personnel

23 NASSCOM: National Association of Software and Services Companies, India.

24 CII: Confederation of Indian Industry.

and policy makers happens through industry consortia, many of our interviewees expressed concern that R&D personnel have limited voice in the engagement of these organizations with policy makers.

B.4.2 **Direct engagement**

In rare instances, Indian policy makers do seek inputs from MNE R&D personnel in evaluating government-funded R&D proposals or on specific S&T policy issues. But there is a lack of systematic mechanisms to translate technical inputs from these experts into policy design and implementation.

Technical experts at major MNE R&DCs are willing to engage with policy makers, beyond their roles as MNE representatives, and provide technical inputs on issues related to technology policy, standards, and capabilities-building in the country. However, the biggest hurdle in MNE R&DC-policymakers engagement is the low perceived legitimacy of MNE R&D personnel among Indian government officials. Based on experiences of multiple interviewees, this is because so far mainly sales and marketing representatives of MNEs have been interacting with Indian policy makers, even on technology policy issues. They primarily focus on convincing the government to procure their products and are not able to provide sound technical advice.

The second major challenge is the shortage of avenues like technical forums—like CCICI[25]—which bring together researchers from different parts of the innovation system and also act as a bridge between the policy makers and the technical community. The few existing active technical forums in India also struggle to find a sustainable funding model.

25 CCICI: Cloud Computing Innovation Council of India.

Linkages between MNE R&DCs and policy makers in India	
Outcomes and implications	**Key factors influencing linkages**
Sound technical input to STI policies—much needed for effectiveness of policies and success of innovation initiatives of government	Low perceived legitimacy of representatives of MNE or MNE R&DCs among policy makers Initiative taken by policy makers to engage with R&DC personnel ** Presence of systematic mechanisms put in place by policy makers to incorporate technical advice into policy design and implementation ** Presence of active technical forums which could act as a bridge between policy makers and technical community ** Willingness of MNE R&D personnel to engage with policy makers **

Supplementary Table 6

Key takeaways about linkages between MNE R&DCs and policy makers in India. **These factors positively influence the respective linkages.

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