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Research Paper

Modeling Doctoral Population Growth in Premier Technology Institutions in India

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Abstract

The present study utilizes the basic reproductive number 'R_0' to make sense of the Indian Institute of Technologies' (IITs) doctoral population growth. The analysis shows that the R_0 for seven IITs under study, and for the engineering disciplines in these IITs, has increased over time. The estimation shows that for the seven IITs, every faculty member, on average, graduates 12.81 PhD students during their entire career. For the engineering disciplines this rate is 11.3 PhD graduates per faculty. This implies that in a steady state only 7.8% of PhD graduates can secure faculty positions in IITs. This, further, shows that the remaining IIT PhD graduates need to find employment outside IIT academia. Moreover, engineering disciplines with a high R_0 show higher research productivity compared to those with a low R_0 which gives scope for the latter to make improvements in their future research activities.

Keywords: IIT PhD graduates; IIT faculty; R_0; Kakodkar committee report; IIT engineering disciplines

INTRODUCTION

The growth of any nation is highly dependent upon its educated manpower. For a developing country like India, it is necessary to maintain a robust, educated workforce to enable continuing economic growth. As an emerging leading economy and to sustain this in a highly competitive world, India has to promote higher education; hence, technical education is of special concern. Here, we highlight the importance of a group of premier institutions of higher technical learning, collectively known as the 'Indian Institute of Technology' or IITs, in India, which are the best engineering teaching institutions in the country. These institutions have attracted global attention through high quality undergraduate, graduate and doctorate alumni which are on a par with other international institutions. The IITs offer world class research facilities and a pool of promising faculty members in the country. The Indian Institute of Technology Act of 1956 declared IITs to be "institutes of national importance", and the central government funds over 80% of the IIT budget (Varma and Kapur, 2010). IIT group is one of the best engineering institutes in India and the entire continent according to the World University Ranking List (QS, 2018). IIT products have had a significant influence in various domains of science and technology. Together, this group of institutions has created the best platform for innovative minds to lead the overall economic growth of the country.

India has educated undergraduate and graduate manpower in diversified disciplines but remains behind in research-oriented manpower when compared with other leading economies. USA and China (a close competitor of India in many aspects) produce around 8,000 to 9,000 PhDs in engineering and technology compared with approximately 1,500 to 2,000 for India (Kakodkar et al., 2011; NIRF, 2017). The majority of PhDs in technology in India come from IITs. Still, the position of IITs in the world ranking of universities is low. The reason for this is usually cited as there being fewer doctoral graduates and the hence annual research outputs when compared to universities in other countries. For a growing country dominated by a knowledge-driven economy like India, such a low number of PhDs is not sufficient to face high competition from other world economies and to sustain the growth of the nation through research and development. In this backdrop, to bridge the gap

between the demand and supply of researchers in realizing the growth of the nation in this highly competitive world, it is necessary to increase the number of PhDs graduating from IITs. The same was observed by Kakodkar et al. in their 2011 report, but there has not been much improvement in the IIT research output scenario prevailing to date. Moreover, IITs are presently facing acute faculty shortages even after aggressive faculty recruitment drives (Kakodkar et al., 2011; The Times of India, 2017; Varma, 2012). This, in turn, has resulted in fewer PhD graduates from IITs as the PhD supervision capacity is reduced due to insufficient numbers of faculty. Compared with the total number of PhDs graduating from the IITs, the number of these IIT graduates being employed within the IITs as faculty is very low, as evidenced from Figure 1. Further, the total number of PhDs (i.e., IIT PhDs; other Indian university PhDs; and foreign university PhDs) taking up IIT faculty positions is also very low when compared with the total number of IIT PhD graduates (Figure 1). Presently, the basic reproductive number 'R_0' is utilized to make sense of the doctoral population growth from IITs in India.

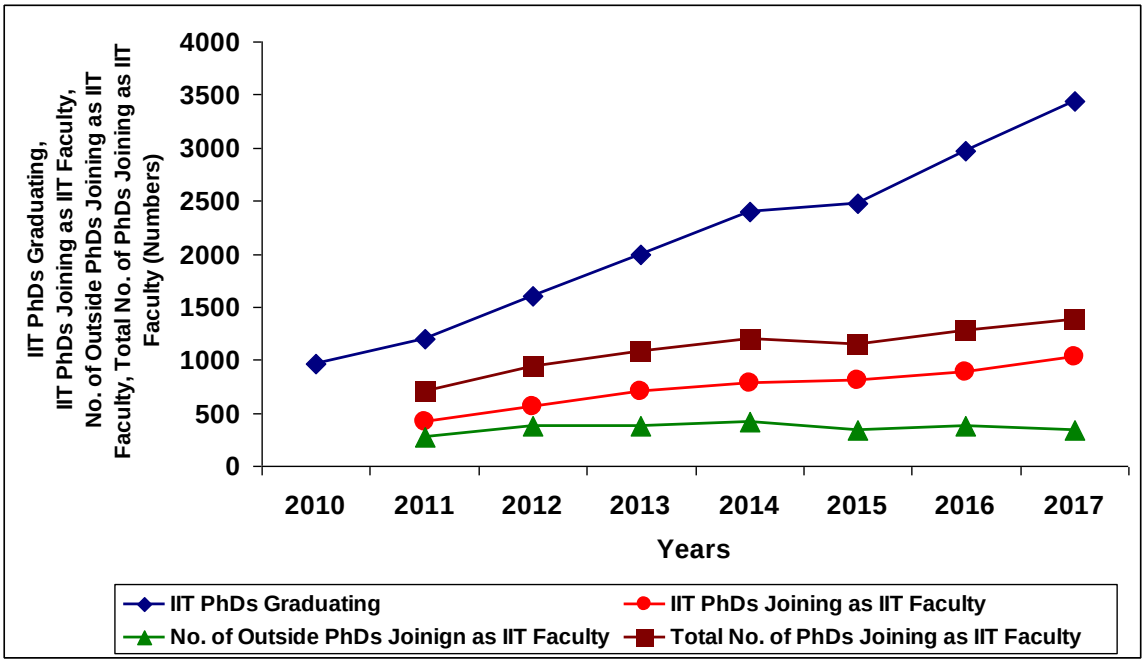

Figure 1 IIT PhDs graduating, IIT PhDs joining as IIT faculty, No. of outside PhDs joining IIT faculty openings and total no. of PhDs joining IIT faculty openings projections (Kakodkar et al., 2011)

THE R_0 CONCEPT IN ACADEMIA

Metaphors have been utilized in many fields of science and technology over several decades. Metaphors from nature as well as other systems have been adopted to explain an entirely different phenomenon present in nature or in a totally different system. For example, the famous systems scientist and academician Professor Barry Richmond taught systems thinking and system dynamics methodology using the metaphor of constructing 'sentences' using nouns and verbs (Richmond, 2004). Here, we metaphor the process of moulding and bringing of the new PhD holder into the world by a faculty to that of a mother giving birth to a child. A faculty member accepts a candidate as his doctoral student, loves and cares him, and will be a torch-bearer to light the path of the candidate throughout his research endeavor. The faculty member will be the guardian and even see their doctoral student as their surrogate son or daughter (Ghaffarzadegan et al., 2015).

The population of a country increases as the birth rate increases. Similarly the doctorate population, which can be seen as 'levels' in the system, increases as there is an increase in their production rate by faculty members. Nevertheless, the extent to which the doctorate population graduating from IITs joins faculty positions in IITs needs to be investigated. At present, there are faculty shortages in IITs in India (Kakodkar et al., 2011; MHRD, 2011, 2015). In order to have an understanding of the current situation of the IIT doctorate holders' population growth, the basic reproduction number 'R_0' is utilized as a simple concept and measurement tool (Larson et al., 2014).

R_0 ESTIMATION

The basic reproduction number 'R_0' can be traced back to the early twentieth century in the works of early demographers like Alfred Lotka. Initially it was defined as the mean number of female children a newly born baby girl will have during her lifetime (Ghaffarzadegan et al., 2015). Analogous to the above definition and following the definition given by Larson et al. (2014), we define R_0 as "the mean number of PhD candidates that a newly joined

faculty member will produce during his or her career in IITs". A R_0 value greater than 1 shows a growth in population over time. A R_0 value less than 1 shows a decline in population over time, and R_0 value equal to 1 shows a stable population. Here we confine our studies to only IITs. There are a total of 23 IITs in India of which seven are mature and 16 new. Here, we consider only the seven mature IITs for R_0 estimation as the others are newly established and in the infant stages of producing PhD scholars. These seven IITs are located at Kharagpur, Bombay, Madras, Kanpur, Delhi, Guwahati and Roorkee. The data for R_0 estimation were collected from the National Institutional Ranking Framework (NIRF, 2017), Council of Indian Institute of Technology (CIIT, 2017), annual reports of IITs, and Kakodkar et al. (2011). The R_0 value is calculated as follows.

$R_0 = \frac{P_t \times M}{F_t}$ where 'P_t' is number of PhDs produced at time t; 'F_t' is the number of faculty at time t; and 'M' is the mean career length of a faculty. On average, faculty members of IITs serve for a period of 30 years which is considered as 'M'. In the present study R_0 values also represent the annual research productivity of the IITs under study. In the equation to compute R_0, the 'M' value remains the same as the R_0 estimates are for the seven IITs and its engineering departments. The other variables of $\frac{P_t}{F_t} = \frac{No.\ of\ \ PhDs\ produced_t}{No.\ of\ Faculty_t}$ give the faculty productivity which can be an indirect indicator of annual research productivity from IITs. More the number of faculty, more PhD students can be supervised to doctoral degree completion which results in increased research productivity in the form of increased research activities, publications and patents. Moreover Crosta and Packman (2005) examined faculty productivity through the doctoral student's supervision. The 'number of faculty' (i.e., total faculty strength) considered in the study to calculate R_0 for the seven IITs includes the IIT faculty with doctoral degrees from IITs, foreign universities and Indian universities other than IITs. The PhD graduates in the present study include all the four categories of doctoral population admitted to IITs. The four category of doctoral students admitted to IITs include institute scholars (direct PhD

intake to IIT), Quality Improvement Programme scholars (faculty enrolled in PhD program), sponsored scholars (employees from organizations other than academia enrolled in PhD program), and integrated PhD scholars (students admitted in the MS program leading to a PhD degree). A rise in IIT PhD graduate population (P_t) will increase the R_0 value. The R_0 values for the seven IITs for 2010 and 2016 are estimated and depicted in Figure 2.

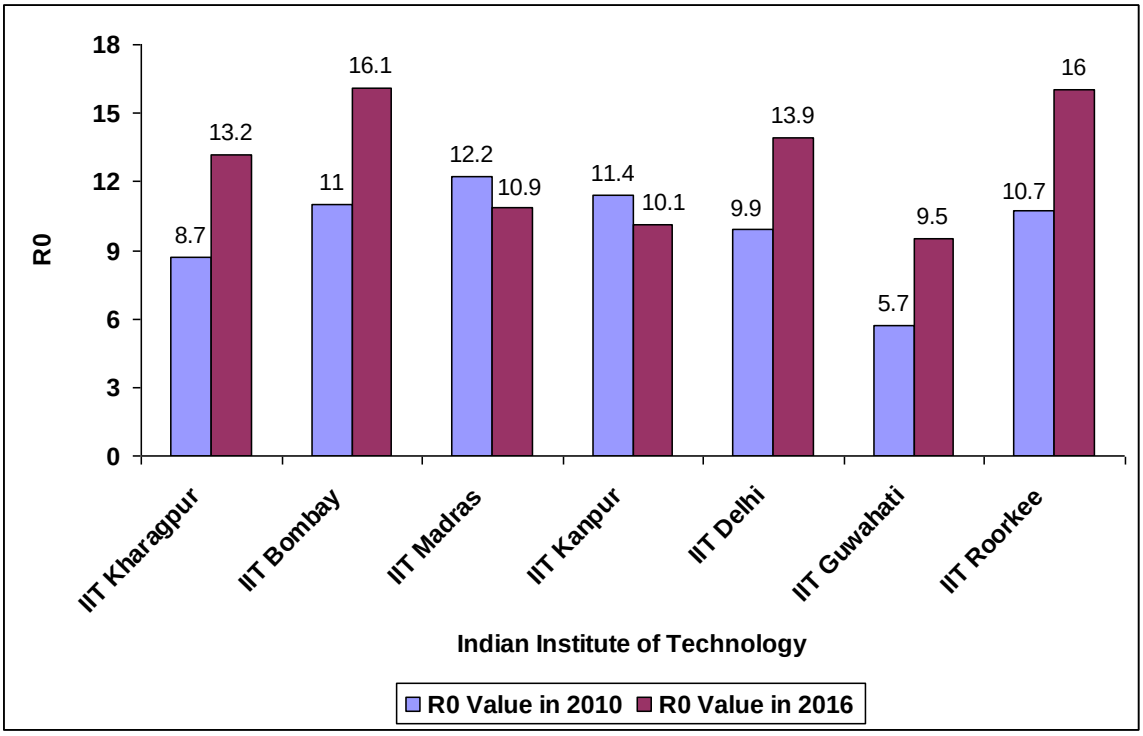

Figure 2 R_0 Estimation for Indian Institute of Technology

As evidenced from Figure 2, the seven IITs have an average R_0 value of 9.94 (approximate to 10) and 12.81 (approximate to 13) for the years 2010 and 2016 respectively. Thus, on an average, the R0 value has increased over time. Thus, as of 2016, an average faculty member in an IIT will produce 12.81 new PhD graduates during his/her career. If the faculty positions are to remain constant, the tenure track assistant professor positions will be available only for 1/12.81 which is 7.8% of new PhD graduates. In 2010, IIT Bombay, IIT Madras, IIT Kanpur and IIT Roorkee attained R_0 values higher than the average. In

2016, IIT Kharagpur, IIT Bombay, IIT Delhi and IIT Roorkee attained R_0 values higher than the average. Within this figure, IIT Bombay and IIT Roorkee have the highest R_0 values compared to other IITs in 2016. Moreover the R_0 values for IIT Madras and IIT Kanpur have declined in 2016 showing a reduction in PhD graduates' production.

R_0 ESTIMATION FOR ENGINEERING DISCIPLINES IN IITS

Apart from the engineering fields, IITs also focus on science disciplines such as mathematics, physics, chemistry, humanities and social sciences, and so forth. The previous section computed R_0 values for all subject fields in the seven IITs under study. The present section focuses on the engineering fields taught and researched in the seven IITs and computes R_0 values for these engineering disciplines. Figure 3 depicts the R_0 estimated values for the different engineering fields in the seven IITs for 2016.

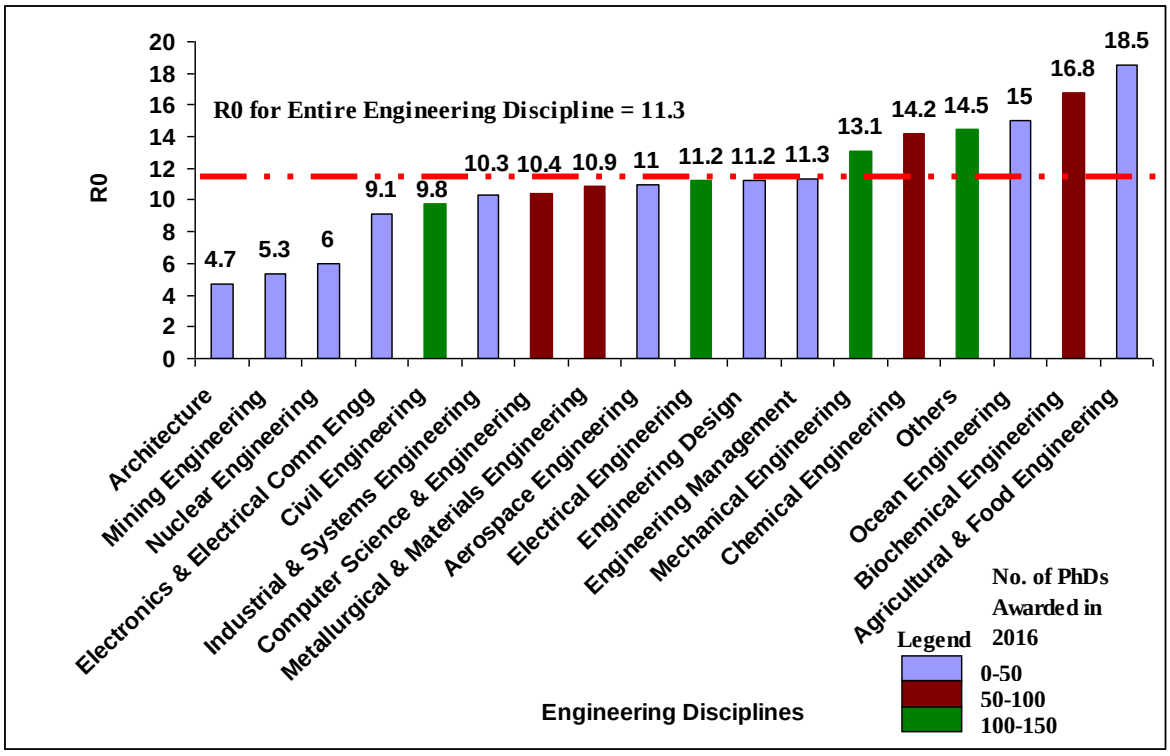

Figure 3 R0 estimation for different engineering disciplines/fields in IITs
(Based on author's calculation from the Annual Reports 2016 of the 7 IITs under study)

Figure 3 indicates a variation in R_0 values across the engineering fields with an average of R_0 = 11.3 for over all disciplines. This indicates that in a steady state, a faculty member of the IIT's engineering department will produce an average of 11.3 PhD graduates in his/her career tenure. If the faculty opportunities in these IITs remain more or less the same, then only 1/11.3, which is 8.8 per cent, of the new IIT PhD graduates will be able to secure a tenure-track position in the engineering departments in IITs under study.

It is evidenced from Figure 3 that there is considerable variation in the computed R_0 values across the different engineering disciplines with a standard deviation of 3.7. Some of the engineering disciplines like agricultural and food engineering (R_0 = 18.5) and biochemical engineering (R_0 = 16.8) have high R_0 values above the field average. Figure 3 also shows the number of PhDs awarded by the different engineering fields in 2016. The light blue bars show the engineering departments that awarded between 0 and 50 PhDs. The brown bars show the engineering departments that awarded between 50 and 100 PhDs. The green bars show the engineering departments that awarded between 100 and 150 PhDs in 2016. The civil engineering, electrical engineering, mechanical engineering and "other" engineering disciplines of the seven IITs produced between 100 and 150 PhD graduates in 2016 with R_0 values of 9.8, 11.2, 13.1 and 14.5 respectively. The computer science and engineering, metallurgical and materials engineering, and chemical engineering of the seven IITs produced between 50 and 100 PhD scholars in 2016 with R_0 values of 10.4, 10.9 and 14.2 respectively. The remainder of the engineering departments produced less than 50 PhDs in 2016.

Figure 3 show that some of the engineering disciplines with high R_0 values produced fewer PhD graduates. For example, the agricultural and food engineering field has the highest R_0 value (18.5). However, the same department produced less than 50 PhD graduates (shown by the blue bar). Contrary to this, the electrical engineering discipline has a low

R_0 value (11.2) but produced more than 100 PhD graduates in 2016 (shown by the green bar). This is because almost all the seven IITs have an electrical engineering department while the agricultural and food engineering department is only present in IIT Kharagpur. This reduces the faculty strength of agricultural and food engineering field considerably which in turn reduces its PhD guiding capacity leading to less PhD graduates from this field. Moreover, the engineering fields with high R_0 values show high faculty productivity and therefore high research productivity compared to those with low R_0 values. Hence, in the above case, the agricultural and food engineering field is more research productive than the electrical engineering field in the seven IITs under study. This is because the research productivity of the engineering field is not determined exclusively by the number of PhD graduates produced but by the ratio of the number of PhD graduates produced to the faculty strength of the engineering field.

STIPULATIONS IN R_0 COMPUTATION

The use of a simple model can have advantages as well as disadvantages. The advantage is that, usually, a simple model can replicate the system behavior more accurately than a complex one (Ghaffarzadegan et al., 2011). The disadvantage is in the form of omission of various parameters that will transform into limitations of the model (Larson et al., 2014). The present analysis does not consider the situation where some of the IIT PhD graduates opt for non-academic jobs either in India or abroad. As such, this group of IIT PhD-holders does not even compete for the tenure-track faculty positions within the country. This can be attributed either to their intentions to take up academic or non-academic jobs in foreign countries or because they have no interest in the teaching profession.

The main advantage of the model is the use of career duration of the IIT faculty which is more or less stabilized at around 30 years. The faculty attrition rate in IITs is considerably less due to the lucrative benefits provided to them by the Ministry of Human Resource Department, Government of India. The IIT faculty receives high salaries, high funding for research, excellent research facilities, travel grants, medical reimbursements, etc.

Moreover, IIT faculty members are generally regarded as possessing high academic quality in their respective academic disciplines thereby making IIT faculty positions prestigious in the country. Thus IIT faculty members remain in their parent institutions for around 30 to 35 years, towards retirement. For the present R_0 computations the estimated career duration of 30 years is adopted. Hence the R_0 values are accurately estimated.

DISCUSSION

The high R_0 values have policy implications as they can significantly influence the demand for funds and employment resources. As of 2016, every IIT faculty member is to produce at least 12.81 PhD scholars (Figure 2) in their academic tenure. This shows a high PhD birth rate. In a steady state condition, of these 12.81 PhD graduates only one can replace the supervising scholar once he/she retires. This, in turn, forces the (R_0 -1) IIT PhD holders to take up positions which do not require a doctoral degree (like IT jobs in India), opt for academic jobs in other universities, non-academic jobs, post-doctoral positions, or migrate to other countries in search of jobs. Moreover, graduate and post-graduate degree holders who are still struggling in the job market consider joining for doctoral degrees to enhance their competitive advantage when securing a future position. The result is more PhD candidate inflows into IITs in the country resulting in high R_0 values and subsequent underemployment of IIT PhD graduates.

In IITs, the retirement age is 65; however, faculty can stay up to the age of 70. This was implemented to partly overcome faculty shortages. Nevertheless, this policy can further reduce faculty openings, resulting in high levels of competition for existing IIT positions and therefore leading to the appointment of high quality PhD holders as IIT faculty. This, in turn, can result in less faculty opportunities in the long-run due to longer retention of newly joined tenure-track IIT faculty.

The Indian Government is undertaking a policy of increasing the annual research output from IITs. Towards this, government has increased the research funds few years back and is

having a policy of instituting more scholarships/funds for outstanding researchers (Indian Express, 2017; NDTV, 2017) that will attract more PhD scholars to IITs. This has already resulted in an increase in the doctoral population in IITs. Increase in doctoral population results in more young research fellows which, in turn, demands for higher funds and, thus, the vicious reinforcing feedback cycle continues. Thus, the increase in doctoral population with no significant change in academic openings in IITs will reduce the opportunity of the IIT PhD holders to secure a faculty position in IIT academia.

The high R_0 values (i.e. $R_0 > 1$) for the seven individual IITs (Figure 2) show that many IIT PhD holders are not successful in obtaining academic positions within IITs. Instead, many of these PhD holders end up in low paid faculty positions in other universities and regional colleges in the country. Unlike IITs, these universities and regional colleges either have no or minimal research facilities and funding. This forces these IIT PhD graduates to produce inferior quality research work in their career. Thus, a large amount of high quality research manpower (IIT PhD graduates) remains under-utilized in the country.

CONCLUSION

The annual research output from IITs can be increased by increasing the number of PhD scholars admitted to the institute. A higher number of PhD scholars will increase the research output from IITs. The present R_0 computation is carried out to gain an insight on the growth of the IIT PhD population, the improvement in annual research output from IITs, and IIT PhD graduates' future prospects in IIT academic job openings, thereby reducing IIT faculty shortages.

From the initial R_0 value analysis for 2016, it was found that IIT Kharagpur, IIT Bombay, IIT Delhi, IIT Roorkee and IIT Guwahati out-perform IIT Madras and IIT Kanpur in research activities. For the seven IITs the average R_0 value was approximately 12.81 in 2016 which, in turn, shows that every faculty member, on average, graduates 12.81 PhD students during their entire career. Thus the high R_0 values (i.e. > 1) for the seven IITs

(Figure 2) imply that there are ample numbers of IIT PhD holders produced to fill faculty shortages in these institutes to a certain extent. Still, the demand-supply gap continues to exist unabated in IITs (The Times of India, 2017; Varma, 2012). The reason behind this IIT faculty demand-supply gap, in spite of high R_0 values, can be attributed to the stringent faculty recruitment standards and procedures in IITs.

The seven IITs' annual research output has increased by 28 percent between 2010 and 2016 (Figure 2). Even though the overall research output from IITs shows an improvement over the years, IIT Bombay has outperformed other IITs in terms of annual research productivity. IIT Guwahati was found to have comparatively low research productivity among the IIT group. Moreover, the individual engineering disciplines with low R_0 values are less productive in terms of annual research output when compared with engineering disciplines with high R_0 values (Figure 3). This, in turn, shows the scope for these low R_0 valued engineering fields to make improvements and, thereby, further increase annual research output in the future.

As the R_0 values for the IITs increase, more IIT PhD graduates will be unable to procure faculty positions within IITs, thereby ending up in non-academic positions or in academic institutes with low research profile or having to travel abroad in search of a job. Moreover, the return of Indian PhD graduates from American and European universities poses an increased threat to this situation. The effect is two-fold: either the high quality research manpower is underutilized; or 'brain drain' to foreign countries occurs. To have full utilization of these 'fine brains' from IITs, the policy makers shall devise polices to prevent their under-utilization and migration to the foreign countries in search of jobs. The policy of increasing the research funding for IITs can alleviate the issue in the short-run. In the long-run, this policy can increase PhD inflow to IITs thereby demanding more funds in the future. One effective policy can be that of creating more diversified research-oriented job opportunities within the country that can attract IIT PhD graduates into joining these government established research organizations. If the country can correctly utilize IIT PhD

graduates to their full capacity, the country can develop further through the increased research activities thereby making the statement “prosperity through discovery” come true.

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