FACTORS INFLUENCING PRODUCTIVITY OF RESEARCHERS: A STUDY OF SELECT PUBLIC SECTOR R&D LABORATORIES IN INDIA

PRE-PRINT VERSION

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Abstract

The R&D spending as well as R&D performance of public sector or national R&D organizations or universities of Asian countries such as China, Japan, Singapore, Korea and Singapore have progressed much in comparison to the India. This indicates that for an improved performance, Indian public sector R&D organizations need to focus on the determinants that improve their R&D productivity. This study focuses upon the determinants of R&D productivity from dual perspective viz. a researchers' perspective, and the research organizations' perspective. This study attempts to outline significant factors that influence generation of R&D outputs such as Patents and Publications. The productivity data of five Indian public sector laboratories have been studied by utilizing correlation analysis and regression modeling to provide facts about the relationship between various aspects of R&D productivity viz. extent of man-days involvement, multitasking in core and non-core R&D jobs and the extent of R&D outputs generated.

Key Words:

VH: Productivity determinants; VH: Benchmarking of R&D Performance; VH: R&D outputs; VH: R&D productivity model; VH: Manpower involvement; VH: Impact and competitiveness; VH: Government research laboratories; H: Age and productivity; H: Qualitative benchmarking; H: Indian R&D organizations; H: Indian R&D laboratories; M: Productivity factors; L: Public funded R&D;

Article Classification: Research Paper

1 Introduction

In this era, both challenges and opportunities for any business are impacted by various factors like digitization of data, access to electronic resources of information and globalization. A novice customer does not exist anymore, and a large number of service providers exist in the market with very competitive offers. Hence, retaining trust and confidence in the eyes of stakeholders, and maintaining one's market space has become imperative for all kinds of businesses. In order to deal with the situation, the organizations must focus on improving upon their organizational competitiveness. The ability of a firm to deal with any kind of challenges is its unique business strategy i.e. competiveness. The competitiveness of an organization can be gained by improving upon a number of interdependent and interrelated factors that impact the overall efficiency and performance of the organization viz. working environment, products and policies, and employee competencies. Along with this, assessing its overall strengths, weaknesses, opportunities and threats by keeping in view the interests of its internal and external stakeholders is also crucial. Overall a firm must put continuous efforts to gain competitive advantage. Specifically, the organizations that are willing to achieve sustainable businesses must work towards gaining sustainable competitive advantages (Feurer and Chaharbaghi, 1994; Cardy and Selvarajan, 2006; Audrone Balkyte & Manuela Tvaronavičiene, 2010). In the process of gaining competitive advantage, the organizations also need to advance in terms of the products that they offer and the processes that they follow. In order to, upkeep their processes and upgrade their technologies, a variety of R&D outputs are utilized by organizations of all types and sizes, and in all sectors worldwide (Cohen, Nelson and Walsh, 2002). Being funded by the tax-payers money, the public sector/ government funded R&D laboratories and universities together shoulder responsibilities of delivering most crucial R&D outputs as per a country's current and future scientific and technological needs, to be manifest as technologies, patents and products. In order to escalate the quality and quantity of benefits envisaged by their R&D outputs, the R&D laboratories and universities must also put in efforts towards benchmarking their processes and performances as well.

As per the Nature Index (2017) and Schimago Institutions Rankings (2018), the top 10 R&D organizations in the world also include the National Universities and Public Research Universities of countries from the Asia Pacific region like Japan and China. It is evident that these countries have already attained a high level of performance in R&D, however, India is yet to improve its R&D performance to be at par with the world. Further, with respect to the top R&D organizations in Asia Pacific region, the Indian R&D organizations again position at a much lower rank in comparison to the R&D organizations of China, Japan, and Singapore viz. IITs (Rank 14), CSIR (Rank 23), IISER (Rank 39), and TISR (Rank 74) (See Table 2). Also, according to the Organization for Economic Co-operation and Development (2018) (henceforth referred to as OECD) data of year 2017, countries like Japan and Korea spend 3.1% and 4.2% respectively of their GDP on R&D, whereas India spends only 0.6%. It is notable that this amount is mostly spent by research universities and the government R&D laboratories in a country. With respect to the number of researchers, in the year 2014, Korea and Japan employed 6899 and 5386 researchers per million population , whereas India employed only 218 researchers per million population in the year 2015. Despite having second largest population in the world India lags behind others in terms of researchers count as well as the total R&D outputs generated. The data reflected that although countries like Singapore and Korea are having significantly lesser population i.e. 5.51 million and 50.07 million respectively the number of patents filed by them are much higher in number than India i.e. Singapore (9413), Korea (2703), and India (454). Further, India filed extremely less number of patents as compared to Japan and Korea also (See Table 1). Hence, it is high time that the Indian public sector R&D organizations endeavor to revive their functioning, and find mechanisms that can enhance the extent and type of R&D outputs generated by them.

The Indian publicly funded research organizations are also facing "cost-cutting measures" now days. Funding is now performance based, and organizations are being asked to meet a part of their recurring expenses (like salaries), from their own earnings. As a result, it is becoming extremely crucial for the R&D organizations to identify measures which will help enhance such R&D outputs that can retain the revenue earning prospects as well i.e. commercially viable/marketable outputs viz. patents, technologies, and products. The productivity of researchers can be estimated in terms of the extent of R&D outputs they generate viz. the number of patents/publications and the number of technologies developed and commercialized. The productivity of any R&D organization is collective of the outputs generated by the researchers working in the organization, and a number of individual, organizational and environmental factors determine the extent and quality of those R&D outputs (Mauleón and Bordons, 2006; Jyoti, Banwet and Deshmukh, 2008 and 2010). In fact, a variety of independent and interrelated factors have distinct roles to play for providing encouragement to the researchers, at individual, organizational and national levels (Käpylä, Jääskeläinen and Lönnqvist, 2010). Higher the quantity and quality of the R&D outputs, higher the goodwill of the organization in the eyes of its stakeholders. Hence, R&D organizations need to identify and improve upon the set of most appropriate and broadly relevant factors that would enhance researchers' productivity. This forms the premise of the study, and against this background, the objective of this paper has been laid out. The objectives of this study are also based upon an internal study undertaken in one of the public sector R&D organization in India, with an aim of achieving optimal utilization of the R&D manpower. It was found that the average man-days involvement in R&D work was not proportional to the R&D outputs generated by the researchers, there were huge variations. Also, a large number of researchers were not optimally involved in the R&D work as per the standards set by the organization. Hence, the obvious questions for research arises i.e. which factors can enhance the extent of R&D outputs generated? Is man-days involvement a significant factor that influences the productivity of researchers? How can optimum involvement in work be ensured?

A number of authors have outlined different factors that impact generation of R&D outputs but not many studies have been found in the context of Indian public sector R&D organizations as well and researchers working in these organizations. Futher, studies exploring the impact of man-days involvement on R&D productivity are lacking in the existing literature. This paper tries to answer the research questions aforementioned and validate the results statistically. The methodologies utilized for the statistical analysis are correlation analysis and regression modeling, which have also been used by a number of authors in the studies of similar context (See Table D in Appendix 1). This paper mainly aims at identifying factors that influence the productivity of researchers working in select Indian public sector R&D organizations, and examining the significance of "man-days involvement", as an influencing factor. The study is based upon the productivity data of researchers of five Indian public sector/ national laboratories that belong to same umbrella society of research and development in India, and governed by the same rules and regulations. This paper has been structured in sections: *Conceptual and Theoretical Background, Conceptual Model & Hypotheses, Methodology, Results and Discussions, Conclusion and Implications, Limitations and Future Direction of Research.*

2.0 Conceptual and Theoretical Background

2.1 Specificities of the Public Sector

Indian public sector laboratories

The R&D in publicly funded laboratories is primarily mandated towards the welfare of the society. The public sector R&D laboratories in India are of two kinds; one, that are governed directly by specific government ministries /departments/ bodies viz. Defence Research and Development Organization, Indian Space Research Organization, and Defence Metallurgical Research Laboratory; and two, that are governed by specific government ministries /departments /bodies through a society or council. Out of the two aforementioned kinds of laboratories, this study focuses on the second kind of laboratories that are governed by a society/council.

The society/council acts as an umbrella body for a number of constituent laboratories or centers viz. Indian Council of Medical Research, Indian Council of Agricultural Research, and Council of Scientific and Industrial Research. These laboratories are established by the government for catering to the needs of country in several technical areas, and undertake projects of a varied nature (viz. industry funded/ government funded). The characteristics of each of the project types are different with respect to the facilities and flexibilities available, viz. tour grants, capital item grants, and prospects of publications/patents. The industry funded projects include Contract Research/ Sponsored projects (SSP), Collaborative projects (CLP), Consultancy projects (CNP), are of generally short term (6 months-3 years) duration. The government funded projects include Grant-in-Aid projects (GAP), and such projects are generally for longer terms (3-5 years), for a particular project, a researcher can be associated as a leader

(PL), co-leader (CO-PL) or a member. The role of a researcher in a project is determined on the basis of the organizational policy or by virtue of technical competence and/or seniority.

An increasing trend of conducting inter-disciplinary research through inter-institutional networking and collaboration between universities industries and R&D laboratories has made it obvious to have researchers from different academic backgrounds, culture and discipline working together as one team (Landry, Traore and Godin, 1996; Abramo, D'Angelo and Di Costa, 2009). The personal characteristics, skills and abilities as well as competencies are key elements when it comes to deciding about a project team. The ambitions, priorities and preferences of team members also vary; while, some researchers are keen on quick technological innovations, patenting and commercialization, others prefer working on long term basic science research, and desire to publish in high impact factor journals. During finalization of project manpower, due care is taken and caution exercised; yet satisfying the ambitions is a challenging task, and may lead to lower job satisfaction, thereby impacting productivity, and job turnover in organizations. Specially, in today's age, when retention of talented-manpower is a matter of concern for any industrial sector, the welfare of the manpower must be primary concern for the employers (Beffy, Fougere and Maurel, 2012; Chevalier, 2012).

Benchmarking for Performance in Global Perspective

According to Ciurea and Man (2017), benchmarking can help in regularly examining and comparing an organization's performance with respect to other similar organizations that have achieved high performance in generating outputs. Further, the process of benchmarking involves identifying and adopting the best practices in a specific field of operations. In order to identify benchmark R&D organizations, the ranking and performance data of relevant organizations spread worldwide must be referred to. In this context, relevance can be defined in terms of geographic location, similarity of work-culture, and others.

The latest data available from OECD (2018), UNESCO Science Report (2015), The Economic Times (2018), The World Bank (2015) and National Science Foundation (NSF) (2017) have reflected the current status and statistics of research and development in some of the Asian countries like Japan, Korea, China, Singapore and Brazil. The OECD data of year 2017, indicates that India spends the least GDP percentage on R&D, and files extremely less number of patents as compared to others. Publication is another major output indicator in R&D and, as per UNESCO Science Report (2015) China accounts for more than 20% of the world's publication in 2014 and India stands nowhere in the comparison to other countries in the list (See Table 1).

Table 1: R&D Statistics of Select Emerging Countries from Asia

Country	Triadic Patent Families (2015)	Publications (Percentage of World) (2014)	Country Rankings (Journal Publications)	Gross Domestic Spending on R&D (%age of GDP)	Number of Researchers (Per Million People) (2014)	Total Population (In Millions) (2014)	Number of Government Researchers(Percentage of Total Researchers) (2016)

				(2017)			
Japan	17,361	5.8	5	3.1	5386	126.79	4.54
Brazil	67,331	2.3	15	1.17 (2014)	698	206.08	-
China	2,889	20.2	2	2.1	1113	1369.44	19.9
Korea	2,703	4.0	12	4.2	6899	50.07	7.52
Singapore	9,413	0.6 (2017)	32	2.19 (2014)	6658	5.51	5.32 (2014)
India	454	4.7	9	0.6	218	1295.29	77.39 (2015)

According to the Nature Index (2017) the extent of contribution of R&D organizations worldwide (in more than 68 Journals in the form of publications) has been ordered. The top ten R&D organizations are Chinese Academy of Sciences (CAS), China, Harvard University, United States of America (USA), French National Centre for Scientific Research (CNRS), France, Max Planck Society, Germany, Stanford University, United States of America (USA), The University of Tokyo (UTokyo), Japan, Massachusetts Institute of Technology (MIT), United States of America (USA), Helmholtz Association of German Research Centres, Germany, University of Oxford, United Kingdom (UK), University of Cambridge, and United Kingdom (UK). With respect to the R&D organizations in select Asian countries viz. Japan, China, Singapore, Brazil, Korea and India, the top three R&D organizations from each of the aforementioned countries are listed in Table 2. Additionally, Scimago Institutions Ranking (2018) has also ranked the R&D organizations worldwide on the basis of their publications listed in Scopus database. The Scimago global rankings for the aforementioned organizations have also been listed in Table 2.

Table 2: Top Five R&D Contributors (Journal Publications) of Select Asian Countries (2017/2018)

R&D Organization	**Category (National/Public/Private)***	**Rank (Asia Pacific)#**	**Rank (Global)#**	**Rank (Global)^**
Chinese Academy of Sciences (CAS), China	Public Research University	1	1	1
Peking University (PKU), China	Public Research University	3	16	20
Nanjing University (NJU), China	Public Research University	5	25	134
The University of Tokyo (UTokyo), Japan	National University	2	6	42
Kyoto University, Japan	National University	4	19	104
Osaka University, Japan	National University	9	40	158
Nanyang Technological University (NTU) Singapore	National Research University	8	37	59
National University of Singapore (NUS), Singapore	National Research University	13	47	38
Agency for Science, Technology and Research (A*STAR), Singapore	Public Research Agency	51	170	118
Indian Institutes of Technology (IITs), India	National University	14	53	501**
Council of Scientific and Industrial Research (CSIR), India	National Research Council	23	83	132

Indian Institute of Science (IISc), India	National University	39	141	489
Seoul National University (SNU), South Korea	National Research University	18	68	64
Korea Advanced Institute of Science and Technology (KAIST), South Korea	Public Research University	21	77	156
Yonsei University, South Korea	Private Research University	45	155	182

***National (Autonomous body receiving funds from government); *Public (Government Body/Publicly Funded);**

Source: #Nature Index 2017(Ranked on the basis of extent of publications in 65 journal.) , ^Scimago Institutions Ranking 2018(Based on Scopus Data)

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Lee and Park (2005) have conducted a comparative analysis of the national R&D efficiencies of 27 countries. The variables considered in the study are input (R&D Expenditure and Researchers), and output (Technology Balance of Receipt, Articles, and Patents). The results indicate that countries have different characteristics that differentiate their R&D efficiency levels. Moreover, Asian countries have relatively lower efficiencies than the rest of the part of the world. Singapore was found to be overall efficient in generating all the R&D outputs, and Japan possessed high efficiency in generating patents. Countries like China, Korea and Taiwan possessed relatively lesser efficiencies with respect to generation of R&D outputs.

Aksnes, Sivertsen, van Leeuwen and Wendt (2017) have studied the impact of national R&D expenditures on the national productivity of OECD countries in terms of the number of publications generated (as per Web of Science data). According to the authors, between the years 1993-2012, the productivity levels of the OECD countries has not changed much, except for China. Further, an analysis considering the number of researchers as input and number of publications as output, reflect that the productivity of most EU countries remained constant during the period, except increasing figures for Netherlands, China and South Korea.

Erfanian and Neto (2017) have analyzed the relationship of national scientific outputs and inputs (viz. 'labor' and 'capital') for more than 30 countries, and suggest that the increase in scientific output can lead to technological changes. Such changes can further help in achieving productivity and financial sustainability at the national level. The authors conclude that investing in researchers (labour) rather than in research capital, are more important for increasing R&D outputs at the national level.

2.2 Specificities of R&D

Public Sector Productivity

In the landmark study, Smith (1937) has defined productivity in respect of the division of labour in two categories, viz., productive and unproductive. The basic method of calculating productivity is by calculating the ratios of outputs and inputs (Brown and Svenson, 1998; Tangen, 2002; Coelli, Rao, O'Donnell and Battese, 2005; Boyle, 2006; Phusavat, 2013; Coccia, 2017). The higher the value of this ratio, the better would be the performance of the organization, as well as the effectiveness and impacts of various resources and outputs (Pritchard, 1995; Coelli, et al., 2005; Boyle, 2006; Phusavat, 2013; Coccia, 2017).

Ajitabh and Momaya (2004) have reviewed the existing literature, frameworks and models related to the competitiveness of firms, and clustered factors in three facets viz. assets, processes and performance. According to the authors, the assets can include factors such as human resources, technology, financial and intangible; the processes can include strategic management processes, human resource processes, operational processes, marketing processes and technology / innovation management processes,; and the performance can includes productivity, employee, and customer satisfaction, financial to international. According to Kathuria, Raj and Sen (2013), the conventional studies on total factor productivity employed techniques like “growth accounting (non-parametric)”, “production function accounting for endogeneity (semi-parametric)” and “stochastic production frontier (parametric)”. Singh (2017) has reviewed the existing studies related to productivity, and proposed a simplified technique of measuring the total factor productivity i.e. “growth accounting” in the Indian context.

Phusavat (2013) has defined productivity with respect to “wealth generation” for the nation. According to him, profits must be maximized and costs must be minimized. Kim (2015) has advocated the transformation of the functioning of the public sector organizations in Asian countries. According to him, the ‘market mechanism’ of working must be implemented for improving public sector productivity.

Min and Smyth (2014) have analyzed the effects of globalization on firm level productivity in terms of foreign investments and exports. The authors have found positive effects of high foreign investments and foreign equity ownership on productivity. According to Grossman and Helpman (2015), globalization helps the researchers communicate and learn without individually meeting each other. Further, reverse engineering and publishing act as tools for communicating and learning at global levels.

Nagesh and Thomas (2015) have conducted a review of the existing studies that suggest factors impacting success of government funded R&D projects undertaken by the R&D institutions and/or the academic institutions in India. According to the authors, the importance of such projects is high as they are usually undertaken for the development of science and technology at national level. The authors have categorized the factors into eight categories viz. type of project, leader’s competence, team, environment, funding and other resources, management support, collaboration, and degree of difficulty.

According to Coccia (2017), the productivity of public sector R&D organizations is related to the funding resources that contribute in conducting the modern R&D viz. total revenue (state subsidy and contracts) , cost of personnel, other costs, total cost, materials and products (cost), service (cost), leased assets of third parties. Additionally, the high spending on sophisticated equipments, materials, and services has also been marked as crucial by the author.

Impact of Public Sector Outputs on Growth and Development of a Nation

The technological output and the overall productivity of R&D organizations impacts industries worldwide. Productivity in R&D can be calculated in terms of efficiency in the generation of R&D outputs viz. patents, processes, systems, publications, facts and knowledge. Scherer (1982) in his inspiring work, has found significant growth in industrial gains, through employment of R&D processes and products across industries of United States of America. Griliches (1979) has suggested that returns from R&D, must be evaluated in terms of their applicability for the welfare of society, and for social sectors like space, defense, and health. Further, Griliches (1984) in his influential work has observed that both R&D investments and the firm performance also depend upon conditions like the evolution of scientific opportunities in a particular field, and the prospects of a R&D product being sold in an economy. Moreover, Griliches (1994) suggests that improvements in sources of efficiency in productivity viz. quality of labour, capital and technical change, affect the overall national productivity.

Cohen et al. (2002) have studied the impact of public sector R&D on industrial R&D. According to them, the impact of public sector research is high when it comes to the industrial growth of a nation. They also conclude that a large number of solutions (or the outputs of public sector R&D) are used as inputs by industrial researchers. These inputs assume forms of research findings, prototypes, and new instruments and techniques. The authors conclude that a large number of industrial units in the sectors like food, manufacturing, electronics, automobiles and aerospace, are extensively using the technologies and processes developed by public sector R&D.

Thornhill (2006) has emphasized upon the importance of public sector productivity for the economic growth of the country. According to him, the public sector contributes to the development of nation in three ways viz. firstly, by providing employment to a larger set of people; secondly, by providing largest segment of services in the country; and finally, by becoming largest consumer of government funds. According to Boyle (2006) and Linna, Pekkola, Ukko and Melkas (2010), the productivity in public sector should be such that output equals input i.e. the value created for the economy should be equal to the resources provided by the economy.

Greenhalgh (2016) has reviewed the existing literature on innovation and intellectual property with respect to Indian economy. The author has discussed about the science and technology policy of India, and mentioned that from beginning itself, the focus is on achieving “self-sustainability” at national level. The author has further presented that the existing gross expenditure on R&D (GRED) i.e. less than 1% of the total Indian GDP, out of which, the private sector contributes to only 20% of the total expenditure, and the government through government/public sector laboratories and universities contributes 80% of the total expenditure. The author concludes that high publishing activities indicate that the country’s focus is towards conducting basic science, rather than applied science (patenting and new technological development).

Burhan and Jain (2015) have analyzed the extent of financial resources generated (apart from government budgetary allocation) by the laboratories of Council of Scientific and Industrial Research (CSIR), India during 2002-2015. The authors have also analyzed the relationship between such resources generated and the number of patents filed and technologies licensed by these laboratories. The authors have found increasing trends of filing patents and generating non-budgetary financial resources for all CSIR laboratories together. Further, it was concluded that no significant correlation exists between the three variables viz. patents filing, technology licensing, and financial resources generated, and a non-uniform pattern of patents filing and licensing amongst the laboratories was found.

Momaya, Bhat and Lalwani (2017) have studied the role of Indian public sector academic institutes, i.e. Indian Institute of Technologies (IITs) towards increasing Indian industrial growth and competitiveness. According to the authors, the Indian industries are facing trade challenges at global level and expect IITs to increase preparedness of the industries for facing those challenges by creating innovation in the resources they provide to the industry and society viz. *skilled human resource, development and transfer of technology, and entrepreneurship development.* Further, the ability of generating innovative outputs determines the quality and performance of such institutions as well. The authors conclude that there exists several factors that limit the performance of these institutions viz. gaps in strategic intent (e.g. mismatches among elements & with environment), less able to secure industry projects, low flexibility (to revitalize, even after biggest discontinuity), gaps in health and fitness to sustain on challenges, gaps in knowledge, understanding or alignment of key actors.

Factors Influencing R&D Productivity of Researchers

These determinants of researchers' productivity may be grouped into individual, institutional/organizational and environmental categories (Koch and Steers, 1978; Babu and Singh, 1998; Turner and Mairesseb, 2005; Carayol and Matt, 2006; Post, DiTomaso, Farris and Cordero, 2009).

According to a number of researchers (Bonaccorsi and Daraio, 2003; Skirbekk 2004, 2008; Turner and Mairesseb, 2005; Obembe, 2012) the individual factor, 'age' influences R&D productivity in both positive and negative ways. Bonaccorsi and Daraio (2003) have found that productivity declines with the increasing age of Italian researchers. Skirbekk (2004) has found an inverted U-shaped profile of productivity for the age- group of people around 50 years of age. Further, Skirbekk (2008) has again analyzed the determinant 'age', and concluded that age has a positive impact on productivity, especially in those jobs that require skills and experience of elderly people. On the similar lines, Turner and Mairesseb (2005) have also found a 'life cycle' effect of age on the productivity. The individual factors 'field of research', 'research specialization', and 'discipline' have been considered as the determinants of productivity by researchers in past (Abramo et al., 2009; Rotolo and Messeni Petruzzelli, 2012; Krell, 2012). According to Abramo et al. (2009), collaboration at both individual and organizational levels in the form of co-authorship helps in generating large amount of outputs in the interdisciplinary field of research. Krell (2012) has analyzed the effects of discipline of research work on productivity of researchers in the form of number of citations/impact factor of journal publications. The author has warned that before considering the impact factor of a journal as an indicator, the discipline of journal must be rechecked. As the impact factors of some journal(s) tend to be high by virtue of the discipline of the research work they publish. Various job related individual factors have also been studied in past by various authors viz. 'promotion record' and 'job satisfaction' (Kelchtermans and Veugelers, 2011; Strauss, 1966). According to Strauss (1966) the perceptions of government engineers and scientists about the performance variable promotion and job satisfaction is not the same, and the value of the variable changes as per the different experience levels and designations of such researchers. Alternatively, Kelchtermans and Veugelers (2011) have found positive effects of the incentive variable promotion on the productivity of different researchers. The authors conclude that the factor encourages researchers to improve quality of their R&D outputs.

The organizational factors that affect the generation of R&D outputs have been given due importance by the authors of the past studies (Shin, 1999; Ehikhamenor , 2003; Jindal-Snape and Snape, 2006; Anderson, Ronning De Vries and Martinson, 2007; Abramo et al., 2009; Kelchtermans and Veugelers, 2011; Prathap, 2013).

Jindal-Snape and Snape (2006) have analyzed factors that affect the motivation of the researchers of government organizations and have an impact on improving their R&D productivity. The authors conclude that the ability to conduct high quality and curiosity driven research, are highly motivating factors for researchers, whereas factors like lack of feedback from management, difficulty in collaborating with colleagues, and constant review and change act as de-motivators. Further salaries, incentive schemes and prospects of promotion, are not considered to be motivators. Hwang, Jun, Chang and Kim (2017) have studied the perspectives of key personnel working in both R&D organizations as well as R&D planning and management agencies involved in the execution and management of Korean ‘High-risk High-return’ national R&D programs. The authors suggest that merely increasing the flow of government funds is insufficient for increasing the creativity of researchers and research outputs. In order to achieve the desired R&D outcomes, additional measures are necessary like, providing different treatment to varied categories of R&D, flexibility in operating methodology, freedom and responsibility of government ministries, and incentives for valuable failures.

The impact of ‘collaboration’ and ‘co-authorship’ on R&D productivity have also been explored a number of times in the existing literature (Landry et al., 1996; Jindal-Snape and Snape, 2006; Abramo et al., 2009). According to Landry et al. (1996) and Abramo et al. (2009), collaboration in the form of co-authorship (publications and/or patents) between researchers and industry is more productive than collaboration between researchers and their peers or researchers and government institutions. Further, White, James, Burke and Allen (2012) have analyzed the impact of situational variables on the productivity of researchers viz. ‘doctoral student support’ , ‘summer stipends’ and ‘other research grants’, and found that working with students provides free time, and gain resources for the researcher which further helps them write papers in co-authorship and become publishable. Ohly, Sonnentag and Pluntke (2006) and Post, DiTomaso, Farris and Cordero (2009) have studied the organizational factors related to difficult and excess numbers of jobs assignment to a researchers. As per Ohly, Sonnentag and Pluntke (2006), routinization of jobs has a positive impact on the creativity of outputs of the researchers but high complexity of the jobs and high time pressure for completing the jobs are not always welcomed by the researchers.

The factors influencing overall productivity of a R&D organization have been outlined by authors of past studies. According to Oeij, De Looze, Ten Have, Van Rhijn and Kuijt-Evers (2011) and Ragasa (2012), the productivity of researchers can be explained by Q4 - model of productivity (*input quantity, output quantity, output quality, input quality*). Both quantity and quality improve organizational effectiveness, and this effectiveness can enhance the productivity of researchers. According to Prathap (2013) the prime indicators of productivity in the best performing R&D laboratories are number of publications and number of scientists in the laboratory.

The productivity of researchers can also be influenced by various environmental factors. According to Reagans and Zuckerman (2001) and Rotolo and Messeni Petruzzelli (2012), the density and heterogeneity of a researcher’s network in a team help in increasing productivity of the entire R&D team. Further, the long tenure of stay in an organization also helps in increasing productivity. The prime indicators of a researcher’s productivity include variables like number of citations earned by publications, number of downloads of publications, impact factor of publication, and h-index (Vinkler, 2007; Jacso, 2008; Krell, 2012; Prathap, 2013). Vinkler (2007) and Jacso (2008) have suggested that before determining the eminence of a scientist with the help of h-index, the accuracy of the h-index must be verified from as many web sources as possible. Further the “software issues” and “consistency of coverage” of the web databases must also be kept in view, while determining the h-index of a researcher. According to Krell (2012), the impact factor of a journal must be considered along with other variables viz. location and language-group, as these determinants influence the number of citations in a big way.

3 Conceptual Model & Proposed Hypotheses

Based on literature review, and against the context of the research objectives (i.e. outlining the significant factors that influence productivity of researchers), a conceptual model has been proposed in the current study. According to the model a number of factors influence the productivity of researchers working in the Indian public sector R&D organizations. The model is based on the assumption that the productivity of researchers in Indian public funded R&D laboratories manifested through different R&D outputs is influenced by two factors; one, extent of involvement in various roles and type of jobs; and two, significant individual, organizational and environmental factors (See Figure 1).

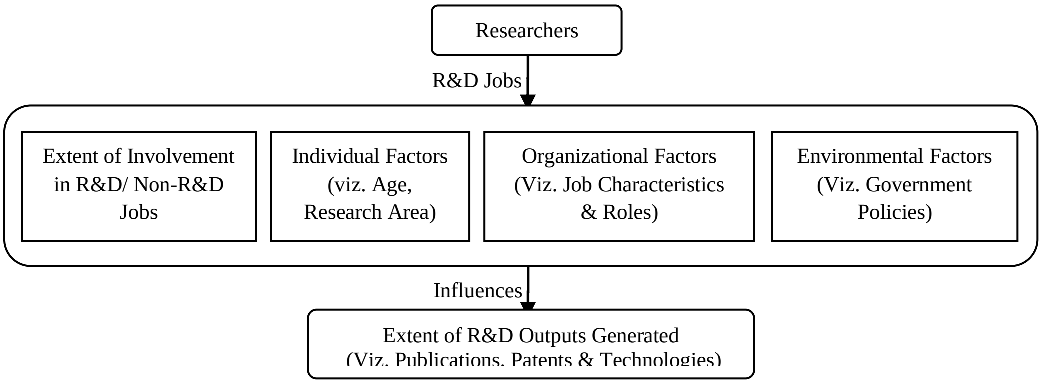

Figure 1: Conceptual framework of factors influencing researchers' productivity

Proposed Hypothesis

The study is limited to a select set of R&D outputs. It aims at identifying a rational set of factors that influence productivity by analyzing the past productivity data of researchers. Further, Kumari, Sahney, Madhukar, Chattoraj and Sinni (2015) have conducted a case study on the productivity data of researchers working in one of the Indian public sector laboratories, and found that the extent of 'man-days' involvement has a positive role to play in enhancing R&D productivity in the form of journal and conference publications. This study further focuses on the role of the determinant 'man-days involvement', of researchers on their achievements and/or outputs.

In R&D organizations, researchers and their intellectual inputs, lie at the core of any R&D or innovation. A set of individual, organizational and environmental factors are responsible for high, average or low productivity of the researchers. Of such factors, the environmental factors can be controlled up to a very limited extent, but the organizational factors can be tailored to suit the needs of researchers. The individual factors can also be improved upon in several ways. By focusing on the relevant factors that impact the performance of the majority of researchers, public sector laboratories can ensure both, an enhanced R&D involvement, as well as the productivity of its researchers. In this context, this analysis focuses on identifying significant factors that have determined the productivity of researchers in the past, and have a potential for enhancing organizational R&D performance in future. The hypotheses of the study are mentioned as follows:

Hypothesis 1: The extent of R&D outputs generated by the researchers' increases with age and experience.

Hypothesis 2: The productivity of researchers is related with the researchers' role as a 'leader'.

Hypothesis 3: The productivity of researchers is affected differently by the different categories of project.

Hypothesis 4: The extent of R&D outputs generated by the researchers is affected positively by guiding and co-authoring with students.

Hypothesis 5: The productivity of researchers is affected by various individual and organizational variables higher than the environmental variables.

Hypothesis 6: The productivity of researchers working in core R&D functions is positively affected by the factor, 'man-days involvement' in R&D projects.

Hypothesis 7: The productivity of researchers working in R&D support and/or administrative functions is positively affected by the factor, 'man-days involvement' in non-R&D projects.

Hypothesis 8: The factor 'man-days involvement' has a positive effect on the productivity of researchers.

4 Methodology

Data Collection and Sampling

The current study has been conducted on a sample of researchers employed in five Indian publicly funded R&D laboratories, situated in different states of the country, and involved in varied core areas of R&D viz. Jharkhand 1 **(**Metals, Minerals and Materials), Jharkhand 2 **(**Fuel and Mining), Odisha (Minerals and Materials Technology), West Bengal (Glass and Ceramic Research), and Punjab (Scientific and Industrial Instruments. The laboratories belong to one umbrella autonomous society, and are governed by same policies and rules. Quota sampling technique was used which provides freedom to the researcher for selection of the sample that is representative of all dissimilar groups of respondents. The researchers were grouped on the basis of their designations and experiences. The data was collected after obtaining permissions from the heads of the institutions, and the data for the years 2011-2015 has been used in the study. The sample profile has been given in Figures 1-4 in Appendix 1. The electronic link of the survey was sent to the respondents on their individual emails. Besides sending the emails, personal visits to the two laboratories in Jharkhand were done, and individual researchers were assisted in filling the questionnaires in one-to-one meetings. Such meetings helped in making the questionnaire much simpler in terms of understanding and led to comprehensive data collection.

Variables and Items

The variables and items for the study have largely been borrowed from studies conducted in the past, in one or the other form. Apart from these, the current study also makes use of additional variables and items, which help determine the productivity of researchers in Indian public sector R&D laboratories. These additional variables and items have been identified and used in the study after consultation with experts from academia and R&D Laboratories. Six R&D output variables and set of factors that affect generation of R&D outputs were selected for the study (See Tables A and B in Appendix 1). A total of 53 input items for the variables were initially considered for the analysis (See Table C in Appendix 1). The variables studied and the methodologies utilized by select past studies in the similar context have been mentioned in Table D in Appendix 1.

Descriptive Statistics, Correlation Coefficients and Robust Regression Method & Models

The “Shapiro Wilk-Test for Normality” revealed that the p-value for all the items was less than the default alpha value of 0.05 (equivalent to the confidence interval of 0.95%). Since the data failed to fit the normal distribution, the normality assumption required for linear regression could not be fulfilled, and so the *robust regression (linear)* method of analysis was used. The Robust Regression (Least Median of Squares estimation) is much less sensitive for the data with significant outliers as compared to the Least Square Regression. The type and strength of association between the items related to the input (independent) and output (dependent) variables of this study were determined by calculating the Spearman Rank Correlation coefficient. The Spearman Rank Correlation is a robust method that is lesser sensitive to the outliers in data (Shevlyakov and Smirnov, 2011). The codes for the items of current study and significant correlation coefficients are tabulated in Table E in Appendix 1 and Table 3. Six Robust Regression models were built with only those set of independent variables which were moderately, (0.40-0.59), strongly (0.60-0.79) or very strongly (0.80-1.0) correlated with the six dependent R&D output variables (See Table 4).

Table 3: Significant Correlation Coefficients

	ECFG	AWDS	HCRD	PTCR	TECH	PUBS
AGE		**0.43**	0.15	**0.41**		**-0.59**
GEN				-0.13		
ACQ				0.14		
YOE	0.15	0.15	0.20	0.29		
CAOR				-0.18		
RENV						-0.13
NORL				0.15		
NPLM		0.24		0.26	0.17	0.29
NOPL		0.34		0.21	0.34	**0.51**
CNPL		0.18			0.24	0.31
CLPL		0.34		0.28	0.28	0.37
SSPL	0.15	0.28	**0.53**	0.31	0.24	0.29
NWPL	-0.13			0.15	0.18	0.17
GAPPL		0.24		0.24	0.35	**0.44**
ACSI				0.31	0.30	0.21
NONC	0.22	0.22	-0.17	0.24	0.27	0.34
NOBQ		0.14		0.22	0.18	0.33
NOSG	0.21	0.30		0.31	0.38	**0.53**
NOPC	0.14	0.40	**0.41**	**0.42**	**0.41**	**0.51**

HIFP	0.26	**0.48**	**0.73**	0.19		0.38
HIND	0.13	0.37	**0.43**	0.16		0.31
NOIT		**0.52**	0.17	0.16	0.33	**0.63**
TIVP			**-0.69**	**0.59**		**0.78**
TIVE			**0.51**	**-0.43**		
TIVN			-0.14	**-0.48**		**0.41**

Table 4: Robust Regression Models

	Multiple R-Squared	**Dependent Variable**	**Independent Variable**	**Coefficients (β)**	**Significance**
Model 1	0.7191	AWDS	AGE31-40	3.0312	***
Model 2	0.7774	AWDS	AGE31-40	2.0938	***
			HIFP	0.4010	**
Model 3	0.7577	PTCR	AGE31-40	1.044187	*
			AGE51-60	0.693100	*
			NOPC	0.102330	***
			TIVE	-0.027703	*
			TIVN	-0.016129	*
Model 4	0.55	HCRD	HIFP	5.47950	***
			NOPC	0.53355	**
			TIVP	-0.12217	**
			TIVE	0.14099	*
			SSPL	0.24842	.
Model 5	0.7231	PUBS	AGE31-40	51.779	***
Model 6	0.8109	PUBS	NOPC	1.8086	***
			NOIT	2.2340	***
			GAPPL	1.2730	***
			AGE31-40	29.0031	***
			AGE Above 60	-28.8775	*
			NOPL	-0.2418	.
			TIVN	-0.1539	*
			TIVP	2.5230	***
Significance codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1					

5 Results and Discussions

The Robust Regression models are tabulated in Table 4. According to Models 1 and 2, the dependent variable ‘awards/fellowships/editorial board memberships’, was explained by the independent variables, viz., ‘age’ and ‘highest impact factor publication’ (journal publication), in 71.91% and 77.74% of the cases in the data set. According to Model 3, the dependent variable ‘patents and copyrights’, was explained by the independent variables, viz., ‘age’, ‘number of publications co-authored with students’ (research students), ‘man-days involvement in equipment handling’ and ‘man-days involvement, in non-R&D activities’ in 75.77% of the cases in the dataset. According to Model 4, the dependent variable, ‘highest citation received’ (journal publication), was explained by the independent variables, viz., ‘highest impact factor publication’ (journal publication), ‘number of publications co-authored with students’ (research students), ‘man-days involvement in R&D activities’ (except equipment handling), man-days involvement in equipment handling’ and ‘number of sponsored projects led’, in 55% of the cases in the dataset. According to Model 5, the dependent variable ‘publication’ was explained by the independent variable ‘age’, in 72.31% of the cases in the dataset. According to Model 6, the dependent variable ‘publication’, was explained by the independent variables, viz., ‘number of publications co-authored with students’ (research students), ‘number of invited talks/lectures’, ‘number of government aided projects led’, ‘age’, ‘number of projects led’, ‘man-days involvement in non-R&D activities’, ‘man-days involvement in R&D activities’ (except equipment handling), in 81.09% of the cases in the dataset.

None of the independent variables were found to be moderately or highly correlated with the dependent variable ‘external cash flow generated’. Hence, no models could be built for ‘external cash flow generated’. Also, only one independent variable, viz., ‘number of publications co-authored with students’ (research students) was found to be moderately correlated with the dependent variable ‘technologies’. The model built with ‘number of publications co-authored with students’ (research students) explains less than 5% of the ‘technologies’. Hence, the model failed to be accepted.

Hypothesis Testing

The hypothesis pertaining to the factors influencing the productivity of researchers were tested and the results are as follows:

Hypothesis 1: The extent of R&D outputs generated by the researchers’ increases with age and experience.

According to the Models 1, 2, 3, 5, and 6 the R&D outputs ‘awards/fellowships/editorial board memberships’, ‘patents and copyrights’ and ‘publications’, were significantly explained by the individual variable ‘age’ in 71%, 75% and 72% of the cases in the dataset respectively. The researchers in the age groups of 31-40 years and 51-60 years, were positively impacted by their ages, and researchers of age above 60 years, were negatively impacted by their ages towards generating the output variable ‘awards/fellowships/editorial board memberships’. Further, researchers who were in the age group of 31-40 years, generated a higher number of R&D outputs in the form of ‘awards/fellowships/editorial board memberships’, ‘patents and copyrights’ and ‘publications’ whereas, the productivity of researchers above the age of their retirement i.e. above 60 years, was negatively impacted by their age, and such researchers were generating comparatively lesser number of R&D outputs. Hence, it may be concluded that researchers in their initial years of service i.e. in 30-40 years age group, tend to be more productive than researchers who are elderly. Hence, it is evident that after a threshold increasing age does not guarantee for higher productivity. Also, the years of service or experience does not always help in yielding higher productivity. Hence, the null hypothesis was rejected.

Hypothesis 2: The productivity of researchers is related with the researchers' role as a 'leader'.

According to Model 6, the dependent variable, 'publications' is significantly explained by the independent variable 'number of projects led', in 81% of the cases in the dataset. The model revealed an inverse relationship between 'publications' and 'number of projects led', i.e. the researchers involved in large number of projects as project leaders and principal investigators, were likely to publish lesser as compared to others. Hence, it can be concluded that research publications are not dependent upon ones position of leadership in a R&D project, and hence the null hypothesis was rejected.

Hypothesis 3: The productivity of researchers is affected differently by the different categories of project.

Model 4 indicated that the extent of R&D output 'highest citation received' (journal publication), was positively and significantly influenced by the participation of researchers in the 'sponsored' category of projects as leaders. This was found true with 55% of the cases in the dataset. Further, findings of model 6 indicated that researchers involved in 'grant in aid', category of projects as leaders also tend to publish a large number of papers. The R&D output 'publications', is significantly influenced by the factor, 'number of government aided projects Led, and hence, the null hypothesis failed to get rejected.

Hypothesis 4: The extent of R&D outputs generated by the researchers' is affected positively by guiding and co-authoring with students.

Despite showing a strong association with the output 'publications', the independent variable 'number of students guided', did not reflect a significant relationship in any of the models. Further, the dependent variables 'patents/copyrights', 'highest citation received' (journal publication) and 'publications', were significantly explained by the independent variable 'number of publications co-authored with students', in 76%, 55% and 81% of the cases in the dataset (Models 3, 4 and 6). Hence, the null hypothesis failed to get rejected.

Hypothesis 5: The productivity of researchers is affected by various individual and organizational variables higher than the environmental variables.

The findings of the regression Models 1,2,3,5 and 6 reflected that more than one R&D outputs was influenced significantly by the factor 'age', either positively or negatively. This confirms the findings of Bonaccorsi and Daraio (2003), Skirbekk (2004), Turner and Mairesseb (2005), Skirbekk (2008) and Obembe (2012), about 'age' being a factor that affects R&D productivity in both positive and negative ways. Models 1-6 also indicated that the organizational variables (independent variables), were significant in explaining one or more R&D outputs (dependent variables), for 55% - 72% of cases in the dataset. While more than one individual and organizational variables were found to be explaining more than one R&D output, only one environmental factor, viz., 'high impact factor publication' was able to explain the R&D output 'awards/fellowships/editorial board memberships ' in 78% of the cases in the dataset (Model 2). Hence, it may be concluded that the individual and organizational factors influence the productivity of researchers much more than the environmental variables and hence, the null hypothesis failed to get rejected.

Hypothesis 6: The productivity of researchers working in core R&D functions is positively affected by the factor 'man-days involvement' in R&D projects.

Findings from the regression Model 6 indicated that the dependent variable 'publications', was very significantly explained by the independent variable 'man-days-involvement in R&D activities', in 81% of cases in the dataset. Researchers having a high man-day involvement in R&D projects also had a large number of publications. Also, Model 4 indicated that in 55% of the cases in the dataset, the dependent variable 'highest citation received' (Journal Publication), was significantly explained by the independent variable 'man-days-involvement in equipment handling'. Researchers having a higher degree of man-days involvement in equipment handling, also achieved higher number of citations. Hence, the null hypothesis failed to get rejected, and it can be concluded that a high involvement of researchers in R&D projects and equipment handling, leads to generation of a large number of publications and citations. Hence, the null hypothesis failed to get rejected.

Hypothesis 7: The productivity of researchers working in R&D support and/or administrative functions is positively affected by the factor, 'man-days involvement' in non-R&D projects.

Models 3 and 6 indicated that the dependent variables, 'patents/copyrights' and 'publications', were significantly explained by the independent variable 'man-days involvement in non-R&D activities'. Researchers who are highly involved in non-R&D activities are likely to generate lesser number of 'patents/copyrights' and 'publications', in 76% & 81% of the cases in dataset. Hence, it may be concluded that the R&D outputs 'patents/copyrights' and 'publications', are negatively influenced by 'man-days involvement in non-R&D Activities' and thus the null hypothesis was rejected.

Hypothesis 8: The factor 'man-days involvement' has both positive and negative effects on the productivity of researchers.

Model 4 indicated that in 55% of cases, researchers with a high man-day involvement in R&D projects (both in terms of large number of projects, and in terms of diversity of projects), tend to receive lesser number of citations. Alternatively, researchers having a high involvement in non-R&D projects, were likely to receive higher number of citations. Model 3 indicated that in 76% of cases, researchers having high man-days involvement in handling equipment and non-R&D projects tend to have lesser number of patents/copyrights. Alternatively, researchers having a high involvement in non-R&D projects, were likely to receive a high number of patents/copyrights. Model 6 indicated that in 81% of cases in the dataset, researchers having a high man-day involvement in R&D projects scored high on the number of publications, whereas researchers having high involvement in non-R&D projects were publishing lesser in terms of quantity. Hence, it can be inferred that 'man-days-involvement', is one of the significant influencing variables for generation of R&D outputs. Hence, the null hypothesis failed to get rejected, and it can be concluded that the productivity of researchers with respect to various R&D outputs is greatly influenced by their man-days involvements in R&D/non-R&D activities in either a positive or a negative way.

Discussion

The findings clearly indicated that, the individual factor 'age', has evolved as one of the most significant factors which impacts the generation of most of the R&D outputs, which have been considered in the study. Researchers in age group, viz. 30-40 years and 50-60 years, were found to be highly active in generating more than one R&D output, whereas researchers above the age of 60 years showed declining productivity (See Figure 5). This confirms to the findings of Bonaccorsi and Daraio (2003), who share similar observations from their study. Moreover, researchers falling in the age group 31-40 years, who were still in the mode of learning, and had relatively lesser experience, generated comparatively lesser amount of any one R&D outputs. Hence, it can be inferred that nurturing, facilitating and encouraging younger researchers is important for R&D organizations so that a continuous succession of next generation performers can be prepared who would ensure productivity of the organization in future.

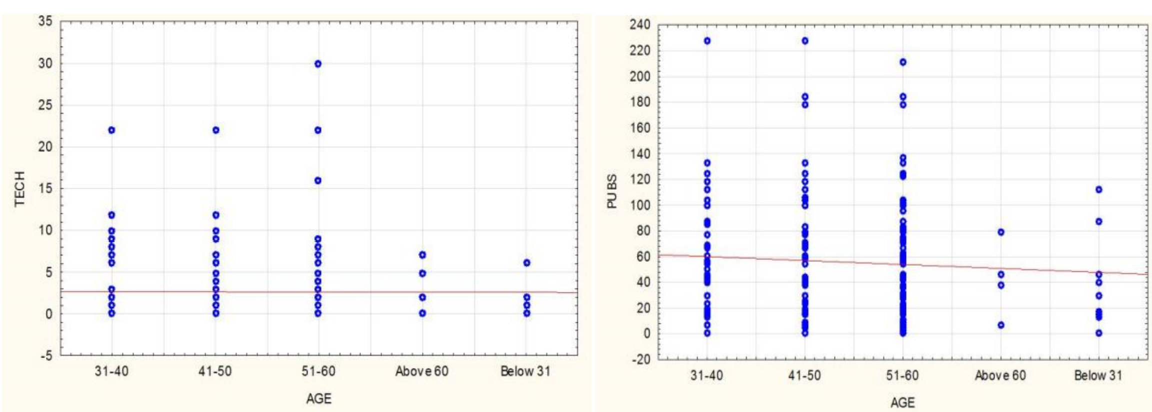

Figure 5: Effects of Age on R&D Outputs

White et al. (2012) have suggested that working with students like summer trainees, doctoral students and research fellows, helps share a lot of load of researchers e.g. writing papers, drafting patents, doing experiments, handling equipment and so on, and the time saved can be used to write papers and co-publish. The findings clearly indicated that researchers who work with a large number of students also co-author a large number of publications with their students and accordingly, generate higher amounts of R&D outputs. Hence, focusing upon the regular inflow of students, and maintaining a pool of distinct categories of students' viz. graduates (summer and winter trainees), masters, and doctoral students (research fellows, research scholars) is crucial especially for organizations that desire to increase their R&D performance.

Researchers perform various roles across different projects like those of project leaders, co-project leaders, members and coordinators etc. As project leaders, researchers invest maximum time in the project as well as are privileged to have key access to details as well as resources pertaining to the project (like objectives, issues and research outcomes, timelines, equipment, data, etc,). However, this high involvement in a few projects, restricts them from involving themselves in a large number of other projects, even as members. On the contrary, researchers who are team members in a larger number of projects are able to get exposure to a variety of research problems. Hence, it can be concluded that 'man-days involvement in R&D projects' and 'total number of projects led**'** are significant factors that can enhance researchers' productivity.

The productivity of researchers can also be affected by the characteristics of various categories of R&D projects. Typically, the Grant-in-Aid projects receive funding for a number of functions, which promote a variety of R&D activities like building state of the art facilities, purchasing highly expensive capital equipments, as well as encouraging its manpower to attending conferences etc. Later, such equipments can be used to solve industry sponsored R&D problems. Researchers are also encouraged to present the findings of their work in conferences, which also leads to papers being published in the conference proceedings. On the other hand, the sponsored projects are advantageous as they involve a researcher for a lesser time span, and deliver high impact solutions for ongoing industrial problems. According to the findings, organizations aiming at a large number of publications, must undertake large number of grant-in-aid projects (Model 6), and the organizations aiming at enhanced citations for its publications, must publish in high impact factor journals (Model 4).

Other significant factors that influence the productivity of researchers are 'man-days involvement in R&D projects', 'man-days involvement in non-R&D projects' and 'man-days-involvement in equipment handling'. A high involvement in non-R&D jobs hinders the process of output generation, and does not help much in generating R&D outputs (Moore, 2004; James, 2011). Hence, in order to increase the number of R&D outputs, the involvement of researchers in R&D activities must be enhanced.

Babu and Singh (1998) have emphasized the role of individual variables more as compared to organizational and environmental variables in generating R&D outputs. According to the findings of this study, the individual variables were found to be significant factors for generating one or more of the R&D outputs. The 'commitment' of a researcher towards delivering R&D services to the client on time, contributes towards earning client's satisfaction, which can increase the inflow of R&D projects, which in turn can enhance the external cash flow for the organization. Further, strong communication skills are extremely important in communication of research and their findings, like funding applications, preparing research reports, publishing papers, drafting patents, etc. Additionally, the 'academic background' generally determines the specialization or the core research area of a researcher. It is observable that there are certain research areas which are able to gain higher citation, and make greater impact due to their wider applicability and scope of mass implementation. Moreover, the 'industry contacts developed' during the execution of R&D projects and organization of events, like conferences and seminars, can generate new leads and new customers for the organization. According to Min-peng and Xiao-hu (2012) 'motivation' is a measure of one's attitude towards work. Unless it is present inside a researcher, all other efforts of the organization would fail. Hence, the 'level of (intrinsic) motivation' is another crucial ingredient in the recipe of conducting successful R&D.

6 Conclusion and Implications

From this study, few conclusions may be drawn. As researchers are expected to fulfill the various roles and fit into various job profiles, the possible solution lies in multitasking. While addressing the two issues viz. one, pertaining to research in basic science leading to national development, and two, pertaining to revenue generation, researchers face challenges like timely delivery of high quality R&D output, and customer satisfaction, and a focus on 'quality' is necessary (Jacob and Lefgren, 2011). Although, the relevance of various factors in generating R&D outputs have been discussed by many authors in past yet, the focus on the extent of man-days involvement in relation with other relevant factors was hardly found. Hence, this study has contributed to the domain of research related to the productivity and job-design of R&D manpower in Indian context. The methodology adopted in the study has remained similar to what several of the earlier studies in the similar context (See Table D in Appendix 1) i.e. Correlation Analysis and Regression Modeling. The analysis of data in this study clearly identified a selective mix of individual, organizational and environmental variables actually lead towards generating a high amount of R&D outputs. The researchers in the younger age group were found to be generating a variety of R&D outputs. This can be an opportunity for the organizations to utilize potential of the young researchers and ensure productivity in the long run by nurturing and mentoring them. The extent of 'man-days involvement' in various categories of R&D projects also contributed in generating R&D outputs. Hence, the R&D organizations must find measures to achieve optimum involvement of manpower in R&D.

Specific categories of R&D projects also helped in generating large numbers of R&D outputs like Publications. In particular, leading government aided projects helped researchers in gaining high productivity. Hence, the R&D organizations must keep a balance between industry funded and government funded projects. Further, a large set of skilled manpower viz. students, project assistants, and research scholars do contribute a lot in achieving the research objectives hence, help in generating R&D outputs. The organizational commitments towards such human resource are not high as the association between the two is for a specific duration only. Hence, the R&D organizations must hire and utilize such valuable intellects optimally in the R&D projects.

Key implications for the stakeholders of the R&D Organizations

This paper attempts at gaining new insights about the management of public sector laboratories by outlining a set individual, organizational and environmental factors, which would be applicable to a large number of researchers and would mutually benefit both the researchers and organizations. The findings would aid R&D laboratories to ascertain and focus upon factors which influence productivity so that R&D policies can be formulated accordingly. The findings of the study provides implications for most of the key stakeholders of the Indian publicly funded R&D organizations viz. *management and researchers of the R&D organizations, funding organizations,* and *customers*. The *management* of the R&D organizations can infer that not all influencing factors impact productivity in the similar way. Hence, they must kick start the exercises that can identify the select significant influencing factors for their respective organizations. In addition to this, implementing measures that can improve upon the manpower involvement in R&D activities would also be advantageous. Enhancement in productivity could impress both *customers* and the various *funding agencies*. The performance of an *organization* plays a significant role in increasing goodwill and establishing trust in the eyes of the stakeholders.

7 Limitations and Future Direction of Research

The study offers meaningful insights regarding productivity of researchers in Indian public funded R&D laboratories. However, it suffers few limitations, which provide ground for the future scope of research. First and foremost, not all the factors of productivity have been explored in the study. For example, the number and type of trainings attended by researchers, prospects of research funding available to them, effects of R&D project specific factors (like deviations in dates, monetary value of projects and team composition), effects of organizational policies etc. have not been included in the study. The study can be further extended in terms of the additional R&D outputs, influencing factors as well as items like the behavioral competency of researchers, effects of policy of transfer and promotion etc. Due to paucity of time and financial constraints, only five of the R&D laboratories mostly from the eastern part of the country were selected to conduct the study, more data could have supported the results in a better way. The priority was given to choosing such laboratories in which data could be obtained timely. Finally, the study has been limited only to the research laboratories belonging to one umbrella government R&D society in India. It could have been comprehensive to include other bodies of research which are governed by various Indian ministries and government departments, and from other parts of the country. This could have help reveal other facts about challenges of productivity. Lastly, as the findings suggested, further studies may be taken up to identify significant measures that enhance the R&D involvement of researchers, contribution and use of the IT. The public funded laboratories in India are also responsible for creating sophisticated facilities for conducting future oriented research. The procurement of foreign equipment involves foreign exchange. Future studies can also consider the ratio of foreign earnings to foreign spends in buying expensive equipment from abroad. This ratio can be an indicator of high productivity as well as equipment utilization.

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Key Questions Reflecting Applicability in Real Life

1. **How to enhance the productivity of researchers?**
2. **Which factors out of individual, organizational or environmental impact the R&D performance of researchers?**
3. **Which factors are most relevant to focus upon while framing organizational policies?**
4. **Which factors impact generation of R&D outputs as well as revenues for the organization?**
5. **How to enhance employee involvement in the core activities of the organization?**

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