A R&D productivity model to achieve self-sustainability for public funded/CSIR R&D laboratories, India

- June 2023, International Journal of Productivity and Performance Management
- DOI: 10.1108/IJPPM-09-2022-0457
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International Journal of Productivity and Performance Management

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Journal:	*International Journal of Productivity and Performance Management*
Manuscript ID	IJPPM-09-2022-0457.R1
Manuscript Type:	Standard Paper
Keywords:	Performance management, R&D Productivity Model, CSIR, Mandays-Involvement, Non –R&D Jobs.

A R&D Productivity Model to Achieve Self-Sustainability for Public Funded/CSIR R&D Laboratories, India

Abstract

Purpose: The paper develops a model for enhancing R&D productivity for Indian public funded laboratories. The paper utilizes the productivity data of five CSIR laboratories for analysis and to form the constructs of the model.

Design/methodology/approach: The Weighted Average Method was employed for analyzing the rankings of survey respondents pertaining to the significant measures enhancing R&D involvement of researchers and significant non-R&D jobs. A model of productivity has been proposed by the authors. Various individual, organizational, and environmental constructs related to the researchers working in the CSIR laboratories have been outlined that can enhance R&D Productivity of researchers in Indian R&D laboratories. PLS-SEM was used to find the predictability of the Productivity Model.

Findings: The organizational factors have a crucial role in enhancing the R&D outputs of CSIR-Laboratories. The R&D productivity of researchers can be improved through implementing the constructs of the proposed model of productivity.

Research limitations/implications: The R&D productivity model can be adapted by the R&D laboratories to enhance Researchers' R&D involvement, increased R&D outputs and achieving self-sustenance in long run.

Practical implications: The R&D laboratories can initiate exercises to explore the most relevant factors and measures to enhance R&D productivity of their researchers. The constructs of the model can act as a guideline to introduce the most preferable research policies in the laboratory for overall mutual growth of laboratory and the researchers.

Originality/value: Hardly any studies have been found that have focused on finding the measures of enhancing R&D involvement of researchers and the influence of significant time-intensive jobs on researchers' productivity.

Keywords*:* R&D Productivity Model, CSIR, Mandays-Involvement, Non –R&D Jobs.

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1.0 Introduction

The scientific and technological solutions provided by public sector R&D institutions are vital for the progress of industries related to defence, health, transport, agriculture, energy, automotive, housing, space, IT, manufacturing, education etc. Moreover, the dependence of industries on S&T services and outputs of R&D viz. patents, know-hows, processes, technologies, consultancy, certified reference materials (CRM) is very high. (Cohen et al., 2002; Thornhill, 2006). R&D has strengthened our capabilities to fight against the pandemic with the help of new drugs, vaccines, medical equipment, affordable masks, and sanitizers. The Council of Scientific and Industrial Research (CSIR), the largest chain of public funded R&D institutions in India has provided necessary R&D solutions to meet the country's need during the pandemic in the form of: Rapid and Economic Diagnostics, New Drugs/ Repurposing of Drugs, Hospital Assistive Devices and PPEs (Rayasam and Mande, 2020). In response to the challenges faced by society and industry, the Indian R&D institutions are expected to facilitate - (a) the adoption and adaptation of foreign technologies to the Indian environment b) build competence to develop a pool of skilled manpower, and c) develop technology incubation and entrepreneurship programs (Sharma et al., 2020; Kumari et al., 2021).

Indian public funded R&D organizations like Council of Scientific and Industrial Research (CSIR), Defence Research and Development Organization (DRDO), and Indian Space Research Organization (ISRO) are expected to justify the research funds provided to them from the tax-payer's allowance (Linna et al., 2010; Phusavat, 2013; Ahyaruddin and Akbar, 2016). The advancements in Internet Communication Technologies (ICT) have channeled global-local transactions viz. e-commerce and virtual teams (Boyle, 2006). According to the Scimago Institutions Ranking 2022(https://www.scimagoir.com/rankings.php?sector=Government&ranking=Research&country=IND), Nature Index 2022 (https://www.nature.com/nature-index/institution-outputs/generate/all/countries-India/government) and the Ranking Web of Research Centers 2019 (https://research.webometrics.info/en/Asia/India) for worldwide government research institutions, none of the Indian public sector research institution ranks amongst top performers. The position of CSIR-India is at 186^{th}, 21^{st} and 378^{th} respectively. Research institutions like Chinese Academy of Sciences (CAS) , French National Centre for Scientific Research (CNRS) and Max Planck Gesellschaft are invariably positioned amongst top ten performing research institutions worldwide. The ranking of the research institutions has been formulated on the quantity (viz. presence) and quality (viz. no. of citations, visibility, excellence, technological & social impact, and research factor) of the journal papers published by them. Hence it is evident that the Indian public sector organizations need to put in greater efforts to increase their R&D productivity.

The terms performance and productivity are often being interchangeably used by the practitioners w.r.t. the researchers and research institutions (Tangen, 2005). R&D Productivity can be defined in terms of efficiency and effectiveness, in using resources and generation of outputs (Pritchard, 1995; Linna et al., 2010). Market-orientation of R&D can improve productivity of public sector organizations in Asian countries and can ensure long-term-effectiveness, and quality in the outputs. (Brown and Svenson, 1998; Tangen, 2002; Bolton, 2003; Karlsson et al., 2004; Chaturvedi and Srinivas, 2012; Kim, 2015). High R&D productivity can build confidence of the stakeholders (viz. funding agencies, leads and customers) towards delivery of the expected R&D outputs, by the research institution (Kumari et al., 2018).

Enhancing R&D outputs and attaining sustainability is the prime concern in the Indian public sector R&D organizations (Prabhakar G.P., 2011; Kılkış, 2017; Aguinis et al., 2020; Lizarralde et al., 2020). This concern can be met by doing industry-oriented R&D and using effective and efficient processes. (Ja¨a¨skela¨inen and Lo¨nnqvist, 2011). Several researchers (Pappas and Remer, 1985; Coccia, 2001; Kim and Oh, 2002; Bremser and Barsky, 2004; Karlsson et al., 2004; Bornmann et al., 2005; Cho and Lee, 2005; Jyoti et al., 2008 and 2010; Banwet and Deshmukh, 2010; Linna et al., 2010; Prabhakar G.P., 2011; Asiaei and Bontis, 2020; Kumari et al., 2020; Lizarralde et al., 2020;Chiara et al., 2022) in past, have studied about the different concepts related to the R&D productivity viz. R&D productivity of public funded organizations, determinants of R&D productivity (researchers and organization), measures for enhancement of R&D productivity, measurement of R&D productivity, R&D outputs, performance management systems, R&D manpower, and balance scorecard and sustainability. Ramírez and Nembhard (2004) have reviewed the available literature on R&D productivity measurement over a period of sixty years and concluded that no generically applicable model on productivity management for knowledge workers has evolved.

The determinants of R&D productivity can 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 et al., 2009). According to Kumari et al. (2021), it is essential to align individual and organizational goals, both short term and long term. Researchers are the strategic assets of the CSIR institutes who work towards the achievement of institutional targets. Hence, the additional challenge of the CSIR institutes is to ensure that the researchers are provided with a suitable working environment. (Roy and Dhawan, 2002; Rana et al. 2013). CSIR institutes also face the challenge of competitive funding along with the marketability of their R&D. Owing to the existing competitive environment, CSIR is striving for self-reliance. Overcoming inherent challenges and finding means for revenue earning would probably facilitate self – reliance (Gupta, 2005; Uttam and Venugopal, 2008; Saraf, 2014; Roy and Mitra, 2018). Hence, achieving self-reliance involves two milestones: (i) improving factors that impact the productivity of researchers, (ii) evolving organizational policies and planning to support R&D. This paper initially proposes a conceptual model regarding the factors that influence productivity of researchers and then presents the findings of various studies conducted, related to the constructs of the final Model to achieve the desired R&D productivity. Finally, the study aggregates the findings, validates the conceptual model, and proposes an R&D Productivity Model that suggests the elements for enhancing R&D productivity of both the researcher and the organization. The model of productivity can help Indian public funded R&D laboratories to achieve self-sustenance by self-reliance. The constructs of the final Model are defined in context of the various studies conducted on the researchers of five selected R&D laboratories of CSIR. This paper has been organized in the following sub sections: Introduction, Conceptual Background, Theoretical Background, Methodology, Constructs of the Proposed R&D Productivity Model, Model of R&D Productivity, Conclusion and Implications, Limitations and Future Direction of Research.

2.0. Conceptual Background

2.1. Public Sector R&D Performance in India

The public sector R&D institutions in India consists of two categories viz. Institutional and Industrial. The national R&D laboratories and R&D institutions come under the Institutional category and the private and public sector industries come under the Industrial category. The major public sector Indian R&D laboratories include Council of Scientific and Industrial Research (CSIR), Defence Research and Development Organization (DRDO), Indian Agriculture Research Institute (ICAR) and Department of Atomic Energy (DAE). According to the "Research and Development Statistics-2019-20" (Source: https://dst.gov.in/sites/default/files/Research%20and%20Deveopment%20Statistics%202019-20_0.pdf) published by Department of Science & Technology (DST), India, the R&D spending and performance of the country is on increasing trend. In the financial year 2017-2018, the national expenditure on R&D increased to 0.7% of GDP (0.6% since 2012). Out of this amount 50% was allocated to the Institutional Category. The R&D manpower was 252.7 per million people. With respect to the R&D outputs: patents and publications, in the year 2018, 32% of the world's patent i.e., 15,550 nos. of patents were filed by Indians and ranked as 7th by WIPO and with respect to publications, India could publish 1,35,788 nos. of articles (NSF data) that had been ranked 3rd by National Science Foundation (NSF), 5th by Scopus and 9th by Science Citation Index (SCI). In 2015-16 and 2016-17 publications were 1,10,000 (NSF) and 1,20,000 (NSF) respectively.

The Economic Advisory Council to the Prime Minister (EAC), India has envisioned several targets for the R&D sector for the year 2022, in the report entitled "R&D book for WEB 2019" (Source: https://www.psa.gov.in/psa-prod/publication/RD-book-for-WEB.pdf) viz. a) More than Double expenditure on R&D to ~ 2% of GDP by 2022 b) Double R&D Exports by 2020 and c) Aspire to be one of the top ten Global R&D Institutions in emerging technologies.

2.2. CSIR-Laboratories, India: R&D Performance

The Council of Scientific and Industrial Research (CSIR) is one of the largest public sector laboratories in India. It has a pan India presence with 38 laboratories involved in research in healthcare, energy, environment, metals & metallurgy, strategic sector, aerospace, biotech etc. The total manpower strength of CSIR laboratories is 10,758 The total R&D manpower strength in the CSIR laboratories is 3,468 (Scientists) and 4,382 (Scientific & Technical Staff). The total number of ongoing R&D projects is 6,864 *[Source: https://onecsir.res.in/Analytics/Overview.aspx as on 19/5/21].* Table 1 highlights the ranking of CSIR-India as compiled by three ranking bodies. Performance evaluation and ranking are essential to remain competitive and introspect on the capabilities and limitations, for R&D organizations (Ciurea and Man, 2017). CSIR-India ranks among the top ten research institutions in India. However, their worldwide ranking is very low. This reflects a need to improvise the quality, quantity, and impact of R&D outputs so that they are globally competitive and facilitate an improvement in the rank. Kumari et al. (2018) have also observed that Indian research institutions lag as compared to research institutions worldwide. Prabhakar G.P. (2011), Kumari et al. (2015, 2018 and 2021), Kılkış (2016) have emphasized the need for enhancing the saleable R&D outputs of CSIR laboratories to achieve self-sustenance and reduce dependability on government grants. Figure 1 highlights trends in R&D funding and R&D outputs of CSIR-India during 2015-21.

"Take in Table 1 here"

"Take in Figure 1 here"

2.3. R&D Manpower: Duty of R&D Productivity

The responsibility of generating R&D outputs lies with the researchers in R&D institutions. In the Indian public sector laboratories, the researchers serve in various roles viz. leader, member, mentor, head of the division and others. Based on their academic and cultural background, every researcher has different qualities, ambitions, and preferences. It is necessary to take care of the individual's aspirations while expecting one to fulfill institutional goals. Hence, it is imperative to align the two, for the R&D institutions and implement suitable institutional policies for the same (Kumari et al., 2018 and 2021). Some R&D outcomes are uncertain and may result in either encouragement or discouragement for a researcher. For e.g., a patent or publication may encourage a researcher but a technology/know how developed but not licensed may result in discouragement for the researcher. There may be several factors influencing the non-transfer of technology/know how such as research area, technology in demand, highly cited publication, industry collaboration, government policies and others. In CSIR laboratories, the R&D manpower is supposed to invest their 80% of their "man-days": (a gender-neutral term-eight hours of a day) for R&D jobs and rest 20% for their self-development activities viz. conferences and trainings (Kumari et al., 2015, 2018).

2.4 Conceptual Model

The conceptual model (See Figure 2) assumes that the quotient of R&D outputs generated by the researchers depend upon the factors that are individual and organizational. The individual factors like preferences w.r.t. the kind of jobs, the area of work and the R&D outputs to be generated. A researcher, who possesses competence in the core R&D domain of the organization, must spend his maximum time in the R&D activities, and a researcher who has been associated with a non-R&D department in the organization may maximize his involvement in the science and technology management (White et al., 2012). A researcher must understand and manage individual factors that may defer the attaining of the final goal i.e., the quantity and quality of the outputs generated (Robeldo et al., 2012; White et al., 2012). Based upon experience and exposure, a researcher works in a variety of roles, and he must balance the amount of involvement in each role.

According to the researchers, it is extremely important for the management to keep the R&D preferences of the researchers while planning future targets and long-term goals. There is a need to implement policies that could take care of individual aspirations while fulfilling organizational goals. The conceptual model assumes that the Indian public funded R&D laboratories may achieve high R&D productivity and self-sustainability by focusing on four factors viz. (a) extent of involvement in various roles and type of jobs;(b) significant individual, organizational and environmental factors; (c) implementation of measures that would enhance the involvement of researchers in R&D activities; and (d) preferences of researchers pertaining to R&D outputs and factors influencing generation of the R&D outputs

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3.0 Theoretical Background

3.1 Public Sector R&D Productivity

Public sector R&D organizations receive funding from the government, and the funds are generated by means of public money or taxes paid by the masses. It is important that the productivity of public funded R&D organizations is enhanced and contribute to the development of society and nation. This section primarily focuses on the studies related to productivity and its enhancement with respect to the public sector R&D organizations.

Griliches (1979) explored the concerns that arise while evaluating the contributions of R&D for increasing productivity. According to the author, existing studies consider a productivity function that reveals financial returns from the overall R&D investment, and not from a specific R&D project. The author concludes 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.

According to past studies, sophisticated information and communication technologies and accessibility to knowledge by all has increased global competition. Hence, it is necessary that both public and privately funded research organizations conduct innovative and world class research with the aim of satisfying stakeholders in the form of patents, processes, systems, publications, facts, and knowledge. Further, communication technologies and publishing activities help researchers globally in communicating and learning without individually meeting each other (Brown and Svenson, 1998; Min and Smyth, 2014; and Grossman and Helpman, 2015;)

The impacts of R&D outputs on industries and economy have been studied many times. According to Scherer (1982) and Griliches (1984), employing new technologies increases the industrial profits many folds and hence, the financial gains must be utilized for social welfare and public goods viz. defense, health and space. Cohen et al. (2002) have outlined the high usage of R&D solutions on Industrial growth as well as national growth. Infact, outputs of R&D are adapted as inputs for further R&D at industries viz. research findings, prototypes, and new instruments and techniques. Thornhill (2006), Boyle (2006), Linna et al. (2010) and Phusavat (2013) emphasize that the public sector must produce for industrial and social growth as per the extent of resources provided to them viz. funding and equipment. The outputs must be useful at all levels of the country. The public sector organizations are the largest consumers of government funds, the largest employers and provide the largest segment of business services and social services. Gupta et al. (2000), Karlsson et al. (2004), Breschi et al. (2005) and Kim (2015) have advocated the scientific collaboration with industry and market-based R&D for the public sector R&D institutions and adequacy of all required facilities for conducting world class R&D.

Past studies have considered publications as the focus of both R&D organizations and R&D assessment systems. It enhances collaboration between R&D institutions, academia, and industries as well. 'Scientific collaboration with industry' increases the number of co-authored papers published as well as earning joint patents. The researchers who have been active in publishing activities were also found to be co-authors of patents. Further, the increase in patenting as well as publishing activities have been found to be directly proportional with each other, and this increase suggests that patents are the by-products of fertile research projects (Karlsson et al., 2004; Breschi et al., 2005; and Chaturvedi and Srinivas, 2012).

Hirsch (2005) comments that while the impact factor of a journal is the most commonly applicable productivity indicator, it may not represent quality of the work; rather it is illustrative of the popularity of a journal. He further says that the 'h- index' may be used as an output indicator of authors but should exclude self-citations.

Linna et al. (2010) have defined 'productivity' as the measure of the amount of output generated per unit of input, and 'public sector productivity' as "implicit to be zero in the national accounts i.e., output = input". The generally perceived output of public sector R&D is the value received from public services, in return for the utilisation of public funds. The authors highlighted that 'effectiveness' is the core element to be considered while enhancing public sector productivity. The views of public sector managers about productivity in public sector R&D assumed two forms viz. 'mechanistic' and 'functional'. The mechanistic view reflects a common point of view about public sector R&D productivity, and the functional view reflects relationships between productivity, effectiveness, and quality. The authors concluded that the R&D productivity measurement system for the public sector must also include aspects of quality and long-term effectiveness.

Ja¨a¨skela¨inen and Lo¨nnqvist (2011) have remarked that the responsibility of the public sector lies in taking note of the budget constraint while producing a select set of services. Accordingly, it is important for them to convert the financial inputs into high-quality service outputs, using effective and efficient processes. The authors also emphasize upon the redefining of, and the inclusion of, intangible outputs in the complex performance measurement systems of public sector organizations.

Kim (2015) has advocated the transformation of the functioning of the public sector organizations in Asian countries. According to the author, the 'market mechanism' of working must be implemented for improving public sector productivity. As the expectations of the country for "quality services" has increased, and the resources being provided to the public sector have decreased, the author suggests eight measures for improving the productivity of public sector organizations, viz., "conduct baseline study on public sector innovation to identify the status quo of member countries; provide customized services to member countries according to their needs; target countries based on their development stages to stimulate the innovation initiatives of individual countries; target areas such as service delivery, regulatory reform, and performance management, which could increase outcomes with less input; utilise the existing know-how and resources of Asian Productivity Organization (APO) tools in areas such as knowledge management, quality management, and other technical expertise; create a database on public-sector productivity to accumulate the knowledge and experiences of member countries and to facilitate benchmarking among members; develop guidelines and manuals for each specific program and area; build capacities of the APO and National Productivity Organization (NPOs) to provide appropriate services to member countries".

3.2. Particulars of Public Sector R&D Performance

Banwet and Deshmukh (2006) have suggested employing the balance score card method for the performance evaluation of R&D institutions. According to the authors, the methodology can help in four perspectives viz. customer (feedback), innovative and learning, internal business processes and financial.

Tijssen and Winnink (2018) have compared the "R&D Excellence" of national universities worldwide. It has been measured by the top 10% of the most cited patents and publications cited in those patents. The authors found a wide variation in the performance of universities worldwide. They explained the various factors causing this variance viz. the size of R&D expenditure which influences the number of cited publications and the degree of university-firm collaboration, availability of human resources and quality of science systems. The authors conclude that the most "innovative" i.e., top ranked national universities contribute immensely to the development of S&T in their respective countries.

According to Pal and Sarkar (2020), the available literature on the evaluation of R&D productivity of R&D institutions have been conducted utilizing secondary data viz. bibliographic data, intellectual databases and there exists a need to conduct similar studies on the comprehensive primary data; to be collected from the institutions. Further, the authors have warned about the manipulation of scientific-facts, inapt writing by researchers in predatory journals and overuse of similar indicators for all institutions.

Choi and Kang (2021) have explored the impacts of satisfaction with R&D projects (funding, duration, and support) on the R&D performance (human resource promotion, quality of outputs, IPR, applicability and transferable in industry, net profits). The authors found a strong relationship of the mediating factors a) satisfactory regional connectivity (collaboration with local universities, industries and research centers and local government bodies) and b) R&D operation management (management of R&D activities & targets, support activities like reaching out to industry, facilities like ICT and equipment) on the R&D performance.

3.2. R&D Performance of CSIR-India

Multiple authors of the past studies have observed huge variance amongst the various laboratories of CSIR-India with respect to a) patenting activities of b) optimum utililisation of R&D manpower skills C) R&D performance (Kumar N. (2013), Roy et al. (2013), Roy and Mitra (2018). According to Burhan and Jain (2015), CSIR-laboratories should put in more efforts for marketing their R&D outputs like IPR and business with non-government sources. The public sector R&D performance can be managed by balance score card methodology (Banwet and Deshmukh, 2006). According to the Tijssen and Winnink (2018) and Choi and Kang (2021), R&D performance is directly influenced by size of R&D expenditure, degree of university-firm collaboration, availability of human resources and quality of science systems, collaboration with local universities, industries and research centers and local government bodies, management of R&D activities & targets, support activities like reaching out to industry, facilities like ICT and equipment. Several determinants impact the performance of the R&D organization. Multiple parameters for enhancing the R&D productivity of public sector organizations have been suggested by Banwet and Deshmukh (2010) and Kumari et al. (2020) viz. project management skills, customer focus, market orientation R&D vision and strategic direction, resource availability, organizational culture, human resource focus, top management committee, teamwork, role of IT systems and optimum involvement of researchers in R&D.

According to Kumar et al. (2017, 2018), the productivity for the CSIR-laboratories can be improved by Commercialization & Technology Transfer, Citations & H-Index. Further, Kumar et al. (2018) have conducted SWOT analysis for the laboratories of CSIR and highlighted various elements of each category that these laboratories possess (See Table 2).

"Take in Table 2 here"

Performance (Individual) and Organizational Performance Growth Factors can eventually lead towards sustainability of the laboratories as well (Gangopadhyay et al. (2018). The authors have compared the efficiencies of public sector R&D organizations worldwide and used input variables (viz. grants received and no. of scientific manpower) and output variables (viz. external cash flow earned, no. of technologies transferred, no. of publications and no. of patents) for the study. The authors highlighted that the Indian R&D laboratory (CSIR-National Physical Laboratory, New Delhi) was locally efficient but globally not so efficient w.r.t. the input variables viz. the research grants received by the laboratory was much lesser than that of grants received by similar institutions in other countries. Further, the authors suggested that technologies reaching to market, increasing technology transfers and commercialization are areas that need improvement.

Roy and Mitra (2018) have explored the relationship of the tacit knowledge (structure, roles, and functions) of the R&D manpower of CSIR laboratories and their R&D performances. Most of the laboratories show similar trends in terms of the R&D outputs. The authors observed that CSIR's research manpower is engaged in overlapping functions viz. R&D, Plant & Equipment Handling, Mentorship and Administrative & Support. Hence, there is a need to explore the core-competency of the researchers and utilize them optimally.

Kumari et al. (2021) have studied the preferences of researchers of CSIR laboratories with respect to the R&D outputs and the significance of factors that influence those R&D outputs. It was found that "External Cash Flow" was the most preferred R&D output yet; researchers were more interested in higher number of citations for their publications. This reflects the difference in preferences and reality of R&D outcomes. A need for competency-mapping exercise and including preferences of researchers in setting R&D targets is essential for achieving the desired R&D goals.

3.3. Measures for Sustainable R&D

The importance of reducing dependability on government sources for funding has been emphasized by several authors of past studies (Prabhakar G.P., 2011; Kılkış, 2016; Aguinis et al., 2020; Rayasam and Mande, 2020; Lizarralde et al., 2020). According to the authors, the measures for improving the self-sustainability aspects can be a) set a broader target and mechanism to work as an institution and not as individual laboratories, b) conducting industry–oriented R&D along with fundamental research, c) implementing the best practices of the top R&D institutions worldwide d) focus on human-resources welfare and competency-management e) keep in mind the stakeholders' expectations.

Prabhakar G.P. (2011) has presented the thoughts of Dr. R. A. Mashelkar, Former Director-General, CSIR, on transformation of a government funded R&D institution into a customer-focused, commercial and financially independent institution viz. working together as an institution rather than individual laboratories, conducting R&D that is implementable for the industries and not engaging only in fundamental science, reducing dependability on government funding and self-earning for self-sustainability.

According to Aguinis et al. (2020), several firms have initiated activities during the COVID-19 outbreak, under the banner of CSR. Although CSR has been considered as an activity to enhance sustainability of an organization yet, firms must follow strategies to avoid employee burn outs and risks in the process. According to Rayasam and Mande (2020), CSIR, through its CSR initiatives provided solutions for the mitigation of Covid-19 through five verticals viz. Digital and Molecular Surveillance, Rapid and Economic Diagnostics, New Drugs/ Repurposing of Drugs, Hospital Assistive Devices and PPEs and Supply Chain and Logistics Support System.

Lizarralde et al. (2020) have advised R&D centers to put in the 'innovation' aspect to the R&D and develop selective technologies such that they take minimum time to reach the industries and enhance sustainability. The authors have suggested a model based on Multiple Criteria Decision Making (MCDM) (viz. AHP, ANP) for selection of the most suitable technologies. The model can select the successful technology through technology characteristics (maturity, relevance, and market), competence of the R&D center (qualified manpower) and industrial scenario (acceptable costs). The authors came up with the various criterion of the model viz. a) Maturity (development cycle, technological risk) b) Relevance (originality, potential of extension, patentability) c) Market (dimension, fragmentation, competitors) d) R&D Center Internal Factors (professional capabilities, equipment, alignment with strategy, access to the market, costs, timing) and e) Customers Internal Factors (professional capabilities, equipment, alignment with strategy, costs, timing).

3.4. Framework for enhancing Public Sector R&D Productivity

Banwet and Deshmukh (2010) have studied the factors that improve the performance of the Indian National R&D organizations and have designed a model that could explain cause and effect relationship between the impact of factors and the performance of the organizations. According to the authors, the R&D organizations need to focus on relevant factors at strategic and operational levels and the interdependence between them viz. project management skills, customer focus, market orientation and overall performance of the organization are strongly connected. The authors conclude that factors like R&D vision and strategic direction, resource availability, organizational culture, human resource focus, top management committee and teamwork are critical factors for the organization's better performance.

Kumari et al. (2020) have outlined the role of IT systems in enhancing R&D performance of researchers. According to the authors, the website "Man-days Involvement" is being used at the CSIR-National Metallurgical Laboratory, India for reporting the extent of R&D involvement of researchers in terms of "Man-days (working-days)". The website also provides information on the extent of "External Cash Flow" generated by the researchers. R&D involvement and earnings of researchers are considered as performance indicators in the annual performance evaluation of the researchers. The authors conclude by presenting how the web-based e-profiling system has helped in achieving the optimum involvement of researchers in R&D and eventually reduced the number of researchers having no utilization or zero man-days involvement in R&D. Hence, such web-based information systems can also help to mitigate serious human resource problems viz. optimum utilization of manpower in R&D organizations.

4.0 Methodology

4.1. Data Collection and Sampling

The data was collected through a questionnaire, from five Indian R&D laboratories situated in different states i.e., Jharkhand, Odisha, West Bengal, and Punjab, in the year 2018. The sampling technique "quota" was used to select researchers on the basis of their experience and designations. The laboratories selected for this paper conduct R&D in (i)Metals, Minerals and Materials (ii) Fuel and Mining, Minerals and Materials Technology (iii) Glass and Ceramic and (iv) Scientific and Industrial Instruments. The age group of respondents were: Below 31 (10), 31-40 (76), 41-50 (72), 51-60 (79), Above 60 (4). The highest educational qualifications of the respondents were: PhD (181), Postgraduate (47), Diploma (1), and Others (2). Out of the sample of 300 researchers, 242 responses were complete in all respects and were used for further analysis. The items and their sources have been listed in Table 3

"Take in Table 3 (a, b, and c)"

4.2. Weighted Average Method

The preferences of researchers for the measures for enhancing R&D involvement of researchers were collected in the form of rankings. These rankings had to be done in the range of 1-5. The responses were analyzed through the *Weighted Average Method, which* includes (a) assigning weights to every rank; (b) adding scores of products of ranks and weights; and (c) averaging total weighted score of a choice with the total weighted scores of all ranks of all choices. The average of the rankings obtained through the survey was calculated for each of the choices to determine which the preferred choice was by most of the respondents. The choice with the largest average was the most preferred. The ranking average for a choice was calculated as follows:

w = weight of ranked position   x = total selections for a rank

Weighted Score of a choice= x1w1 + x2w2 + x3w3 ... xnwn

$$\text{Average Weighted Score of a choice} = \frac{\text{Weighted Score of a choice}}{\text{Sum of Weighted Score of all choices}}$$

5.0 Constructs of the Proposed R&D Productivity Model

5.1. Significant R&D Outputs and Influencing Factors in Reality

The authors of this study have conducted a comprehensive study on the factors influencing the productivity of researchers working in the Indian public-funded R&D laboratories (Kumari et al., 2018). The authors have conducted the study on the R&D productivity data of 242 researchers of various laboratories of CSIR. The authors have framed a conceptual model that illustrated the impact of R&D jobs, extent of involvement in those jobs and various individual, organizational, and environmental factors on the productivity of researchers, working in select CSIR laboratories. The authors have concluded that more than one combination of the constructs of the model impact the productivity of a researcher either positively or negatively. Six most relevant R&D Outputs and Factors that Influence generation of each R&D output have been suggested by the authors. The study employed statistical tools like Spearman Rank-Correlation Coefficients and Robust Regressions and has suggested the most significant R&D outputs and influencing factors that help generating the R&D outputs (see Table 4).

"Take in Table 4 here"

Other major findings of the study are:

Part of the study has suggested that a mix of individual, organizational and environmental factors impact the generation of R&D outputs. These factors are age, academic background, commitment, communication skill, industry contacts developed, level of (intrinsic) motivation, working with students, role of a researcher in projects, type of project and extent of involvement in various job types (man-days involvement). R&D laboratories need to implement measures to increase R&D performance, probably through exploring influencing and ensuring maximum involvement of R&D manpower in R&D related jobs.

In the current study, the first set of constructs has been conceptualized on the significant R&D Outputs and the significant influencing factors found in the detailed study conducted by the authors.

5.2. Preferred R&D Outputs and Influencing Factors

The authors of this study have further explored the role of assessing the working preferences of researchers in aligning the R&D goals of researchers and the CSIR-India laboratories (Kumari et al., 2021). According to the authors, it is extremely important for the management to keep the R&D preferences of the researchers while planning future targets and long-term goals. There is a need to implement policies that could take care of individual aspirations while fulfilling organizational goals. According to the authors, it is extremely important for the management to consider the R&D preferences of the researchers while planning future targets and long-term goals. There is a need to implement policies that would take care of individual aspirations while fulfilling organizational goals. This part of the study observed that R&D outputs and factors influencing generation of outputs varied according to the preference of each researcher. This was due to individual aspirations, comfort level, access to resources and personal choice. Hence, it is vital for the public-funded R&D institutions to explore the preferences of the R&D manpower about the research they are interested in conducting and to focus on factors that are relevant from the researcher's perspective. This can help to mitigate the gaps between organizational and individual R&D plans and targets. The study has been conducted employing analytical techniques like Weighted Average Method and Spearman Rank-Order Correlation Coefficients and Robust Regression. An ordered list of the R&D outputs and influencing factors for each of the R&D output has been outlined by the researchers (See Table 5).

"Take in Table 5 here"

Other major findings:

The study highlighted that organizational and environmental factor viz. contacts, infrastructure and collaboration, resources, strategies for Industry-R&D partnerships, organizational culture and policies are very crucial for generating businesses for the laboratories than the individual skills of researchers. The personal attributes viz. eminence of researcher, quality/innovativeness of work, scale of publication and worthiness in the research area are more helpful for individual accomplishments like awards & honours. Further, a gap was identified in the factors that impact productivity of researchers and their preference. It is imperative for the organizations to bridge this gap.

In the current study, one of the constructs of the model of R&D productivity re-emphasizes on identifying the preferences of researchers and mitigating the gaps between reality and preferences as suggested by the findings of the elaborative study conducted by the authors.

5.3 Significant Measures for Enhancing R&D Productivity

It is important to determine and prioritize the measures to be adopted to enhance the involvement of researchers in R&D and also explore the relation of these measures to the factors that influence R&D productivity. Equal distribution of work and increasing R&D involvement of researchers is important for organizations to enhance their overall performance and productivity. According to Kumari et al. (2018), high involvement of researchers in R&D laboratories lead to increased Publications. The measures for enhancing the involvement of researchers were identified through literature review and expert advice (See Table 6). The respondents had to rank measures in the questionnaire in the range of 1-6. The rankings were analysed for the most relevant measures.

"Take in Table 6 here"

5.3.1. Hypotheses

Hypothesis 1: With respect to the measures for enhancement of involvement of researchers in R&D, the organizational factors have a higher relevance.

Hypothesis 1.1: Increasing the number of projects under different categories enhances involvement of researchers in R&D.

Hypothesis 1.2: Increasing the number of R&D projects in the organizations core area of research enhances involvement of researchers in R&D.

5.3.2 Preferred order of the Measures

The weighted average score of the rankings was calculated for identifying measures for enhancing productivity. The weights were assigned to each rank for each of the measures that would help enhance productivity in the following manner: 5 to Rank 1, 4 to Rank 2, 3 to Rank 3, 2 to Rank 4, 1 to Rank 5. All the scores were multiplied with the respective weights, summed up and divided by the total number of selections for all the measures to get the final weighted scores for each of the measure. The overall scores were then converted into percentages to determine the order of preference (See Table 7).

"Take in Table 7 here"

5.3.3. Hypothesis Testing

Hypothesis 1: With respect to the measures for enhancement of involvement of researchers in R&D, the organizational factors have a higher relevance.

While analyzing the rankings and order of preferences for various measures that would enhance R&D involvement, it was found that on an average 14.46%, 13.22%, 11.16%, 9.92%, and 9.5% of the total respondents, ranked Increasing Industry Collaborative projects, Increasing Sponsored projects, Increasing the number of projects in organizations major core area, Linking project participation and R&D outputs to promotions and Increasing Government Aided projects, as the top five measures. All these measures are dependent on the policies of the organization, the competencies of manpower and their willingness to take up research projects. Hence, it can be inferred that improvement of these measures can enhance the R&D involvement of researchers. Hence, the null hypothesis failed to get rejected and it can be concluded that improving organizational factors can help increase the involvement of researchers in Indian public funded R&D laboratories.

Hypothesis 1.1: Increasing the number of projects under different categories enhances involvement of researchers in R&D.

Increasing Industry Collaborative projects, Increasing Sponsored projects and Increasing Government Aided projects were the top five ranked measures. These measures are indicative of the distinctive nature of the projects. The industry collaborative projects and sponsored projects are mostly funded by industries. These projects are of short duration.

Government aided projects are of longer duration and receive government grants Such projects are usually planned projects or network projects and provide solutions to national problems, and/or new technology development for the benefit of the society. They require researchers who are inclined towards basic science research technology development. The findings of Kumari et al. (2018) also revealed that project leaders of both sponsored and government projects generated high number of R&D outputs. Hence, it may be concluded that for encouraging involvement of manpower in R&D a balanced should exist between the various categories of projects and the null hypothesis failed to get rejected.

Hypothesis 1.2: Increasing the number of R&D projects in the organization's core area of research enhances involvement of researchers in R&D.

The measure, increasing the number of projects in organizations major core area was preferred by 11.16% of the total respondents and was placed third in the overall ranking. The available expertise in an R&D organization is generally in its core area of research. Hence, R&D projects in the core area will have a larger participation of researchers.

This study has earlier found that none of the factors related to the research area of researchers was significant. Hence, the preference of researchers regarding measures which help increase employee involvement (increasing core area projects), are incongruent to factors affecting productivity in real life. Further, it can be concluded that merely increasing the number of projects in the core area of a laboratory cannot ensure and/or enhance project participation of researchers. As found from the study of Kumari et al. (2018), R&D laboratories must also consider additional factors like taking up projects in core research areas in industry sponsored, collaborative or government aided categories for enhancing the involvement of its researchers. Hence, the null hypothesis was rejected.

5.3.4 Findings and Discussion

According to the researchers, the selected measures can enhance R&D involvement. The selected measures are also suggestive about the improvisation of such organizational factors that can help in increasing R&D involvement of researchers and revenue generation. Besides this, respondents' views also showed concern for individual career development and well-being. Researchers preferred greater involvement of their respective R&D laboratories in core areas of research, so that the core competence could be enhanced. Although, the measures preferred by researchers were not entirely in congruence with those that influenced productivity, yet these are crucial inputs in the organizational decision-making process. According to 14.46%, 13.22%, 11.16%, 9.92%, 9.5% of the total respondents, the top five measures for enhancing involvement of researchers in R&D were Increasing industry collaborative projects Increasing sponsored projects, Increasing the number of projects in organizations major core area, Linking project participation and R&D outputs to promotions and Increasing government aided projects respectively. Three of these five select measures lay emphasis on undertaking projects like Sponsored, Collaborative and Government Aided. Many researchers are encouraged to undertake sponsored projects as the chances of generating a variety of R&D outputs like Technologies and Patents increases. Such projects not only enhance R&D participation, but also help generate revenues and reserves for the organization. This is in congruence with the findings of Landry et al. (1996), Karlsson et al. (2004), Breschi et al. (2005), Abramo et al. (2009) and Ryu and Choi (2016) about enhancing patenting activities of researchers while practicing R&D collaborations with industries. In contrast, government aided projects have long term goals, which may belong to specific or inter-disciplinary research domains and differ with respect to the nature of project. Such projects are lucrative as they provide a lot of time and flexibility to researchers for conducting basic and applied research, paper writing and attending trainings and conferences. This are consistent with the findings of Foray et al. (2012) and Mishra et al. (2013) that the major outcomes of CSIR laboratories from GAPs have always been new processes, technologies transferred, patents and copyrights, students' employment in various capacities and paper publications having high citations having average high impact factor.

Individual career growth is a priority for researchers. Linking project participation and R&D outputs to promotions can lead to enhanced R&D participation (Choi and Kang, 2021). This implies that career development and financial benefits are of equal importance to the researchers (Griliches, 1979). Hence, R&D laboratories must consider both the priorities of researchers while formulating organizational policies.

The core area of research depicts the strength of an organization, in terms of the available manpower-competence and facilities. Increasing the number of projects in the organization's core area could enhance employee involvement, according to researchers. While the core area of an organization is defined by the major competencies of its employees, the core competencies of employees should be developed so that maximum people can contribute to the core area of the organization (Roy and Mitra, 2018 and Kumari et al., 2021). The core area helps build uniqueness and the brand name for the organization and the respondents in the study opine that this should be further strengthened. Hence, undertaking projects in the core area of the R&D laboratory can inspire greater participation of the researchers (Obembe, 2012).

5.4. Time-Intensive Non-R&D Jobs

This section of the study identifies the most time-intensive non-R&D jobs that are mandatory for the overall functioning of the R&D laboratories. Although several non-R&D activities are crucial for the execution of any R&D project yet, the first and foremost responsibility of a researcher is to conduct R&D. An overload of non-R&D jobs e.g., administration, teaching, mentoring, headship, and committee memberships adversely affect the productivity of researchers (Moore (2004), Giddings (2008) and James (2011). Hence, it is extremely important to identify the non-R&D jobs that are relevant to the organization but are bothersome to the researchers due to their time-intensiveness. This would act as input for redesigning, and re-allocation of jobs so that imbalance can be avoided. R&D laboratories comprise both R&D and R&D-support divisions. The support divisions like administration, internet communications and technologies, stores and purchase, business development, and finance and accounts are expected to support the core R&D function. Though separate manpower is designated to perform the non-R&D jobs yet, some of the non-R&D tasks are delegated to core researchers. Some researchers are assigned roles of committee chairmen, heads of divisions, mentors, teachers, etc. Researchers often must take up the role of heads of division (both R&D and non-R&D divisions) which leads to a diversion from their research activities.

Although such a shift impacts the R&D productivity of researchers yet, the shift is important as it helps researchers develop administrative and managerial skills which may be required at senior positions. So, the involvement in non-R&D activities must have a twofold objective: (i) foster administrative and managerial skills of the researchers (ii) maintain and /or increase their efforts in R&D activities, to enhance their productivity.

A set of select non-R&D jobs that are highly time-intensive, but significant for any Indian public funded R&D organization were identified through literature review and expert advice. They are provided in Table 8. Respondents were asked to select those non-R&D jobs, which were indispensable and time-consuming. The responses were analyzed to identify the most crucial and time-intensive non-R&D activities.

This part of the analysis aims to rank the non-R&D jobs that are unavoidable, time-intensive and require involvement of researchers. This analysis can pave the way for redesigning and distribution of the non-R&D jobs, to lessen the burden on the researchers, and increase their participation in core R&D activities.

5.4.1 Non-R&D Jobs

"Take in Table 8 here"

5.4.2 Hypotheses

Hypothesis 1: With respect to the proportion of non-R&D jobs, the factor age has a high relevance.

Hypothesis 1.1: Several Science and Technological management and administrative jobs are included in the job profile of the researchers along with R&D projects.

Hypothesis 1.2: The extent of man-days involvement in R&D support and administrative jobs varies in different age groups of researchers.

Hypothesis 1.3: The extent of man-days involvement in R&D activities and non-R&D activities are inversely proportional to each other.

5.4.3 Methodology and Select Non-R&D Jobs

This section of the analysis identifies the non-R&D jobs which though significant for Indian publicly funded laboratories, are also perceived to be most time intensive. The respondents were presented with a list on non-R&D jobs and were asked to indicate their participation in such activities. The responses that were obtained from the respondents were compiled and frequency distribution was obtained.

5.4.4 Preferred Order of Non-R&D Jobs

The frequency for each of the non-R&D jobs as indicated by the responses obtained from the respondents (researchers) helped determine their order of preference (See Table 9).

"Take in Table 9 here"

5.4.5 Hypothesis Testing

Hypothesis 2: With respect to the R&D productivity of researchers the extent of non-R&D jobs and the factor age has a high relevance.

The findings of phase one of the study indicated that the individual variable, Age and the organizational variable, Man-days Involvement in Non-R&D Activities were able to explain more than one R&D output variable in the dataset. According to Kumari et al. (2018), the individual variable, Age was significant in explaining the R&D outputs Awards/Fellowships/Editorial Board Memberships, Patents and Copyrights and Publications in 71%, 75% and 72% of the cases in the dataset respectively. The productivity of researchers in the age groups, 31-40 years and 51-60 years indicated a positive relationship with the three output variables, and the productivity of researchers aged above 60 years indicated a negative relationship with the output variables. Further, a negative relationship between Man-days Involvement in Non-R&D Activities and the R&D outputs Patents and Copyrights and Publications was found by the authors for 75% and 72% of the cases in the dataset. Hence, it may be concluded that the amount of non-R&D involvement and age together influences productivity, and thus the null hypothesis failed to get rejected.

Hypothesis 2.1: Several Scientific and Technological management and administrative jobs are included in the job profile of every researcher along with R&D projects.

The responses obtained from the researchers regarding their participation in non-R&D jobs indicated that all of them were involved in some non-R&D activity. The five non-R&D activities, viz. Committee Memberships/Meetings, Mentorship/Students Guided, R&D Support, Purchase and Organization of Events were selected by 13%-21% of the researchers which reaffirmed the assumption in the null hypothesis. Hence, the null hypothesis failed to get rejected.

Hypothesis 2.2: The extent of man-days involvement in Scientific and Technological management and administrative jobs varies in different ages.

According to Figure 3, researchers belonging to the various age groups in the dataset were involved in the non-R&D jobs, "Man-days Involvement in Non-R&D Activities", in the average range of 20%-30%. The percentage of involvement in age groups 31-40 years and above 61years (i.e., very initial years of service, and post- retirement) was lower than other age groups. The dataset did not reflect any drastic variation in the percentage involvement of researchers at different ages. Hence, the null hypothesis got rejected.

"Take in Figure 3 here"

Hypothesis 2.3: The extent of man-days involvement in R&D activities and non-R&D activities are inversely proportional to each other.

The non-R&D jobs, viz., Committee Memberships/Meetings, Mentorship/Students Guided, R&D Support, Purchase and Organization of Events were chosen by most of the researchers as the top five most significant, but time-intensive jobs. It can be assumed that as the involvement in non-R&D jobs increases, the extent of involvement in R&D activities decreases. The scatters plot in Figure 4 indicates a similar trend pertaining to the total man-days involvement of the researchers in the dataset. As the average percentage of involvement in R&D projects increased, the average percentage of non-R&D involvement, Man-days Involvement in Non-R&D Activities (TIVN) decreased. Hence, it can be concluded that the extent of involvement in R&D and non-R&D activities are inversely related to each other, and thus, the null hypothesis failed to get rejected.

"Take in Figure 4 here"

5.4.6. Findings and Discussion

The findings revealed that apart from their involvement in R&D jobs, almost all researchers of public funded R&D laboratories of India, were also involved in non-R&D jobs. However, their degree of involvement in specific non-R&D jobs varied largely, in the range of 3%-21% (Table 9). The frequency scores revealed that relatively lesser percentage of researchers in the sample, were involved in non-R&D jobs like Client Interaction (Business Development)

(12%) and Customer Service (6%), and a large percentage of researchers were involved in five non-R&D jobs, viz. Committee Memberships/Meetings (21%), Mentorship/Students Guided (19%), R&D Support (13%), Purchase (13%) and Organization of Events (13%). While conducting R&D, researchers tend to carry out several non-R&D jobs, both consciously and sub-consciously. Moore (2004) Giddings (2008) James (2011), The organizational responsibilities of a researcher take multiple forms like R&D functions, R&D support functions and administrative functions (Moore, 2004; Giddings, 2008; James, 2011). In other words, R&D functions involve both R&D and non-R&D jobs (and activities) in various roles and capacities. The analysis of Kumari et al. (2015, 2018), indicated that the man-days involvement of researchers in non-R&D activities, has a negative impact on the generation of R&D jobs. Further, the analysis also revealed that the extents of involvement in R&D and non-R&D activities are inversely proportional. A higher involvement of researchers in non-R&D activities, may reduce their involvement in the core R&D activities (James, 2011).

6.0 Model of R&D Productivity

A model of R&D productivity has been built based on the findings of this study (See Figure 5). The objective of the model is to highlight the elements that can enhance the R&D productivity of any Indian public sector R&D laboratory and can lead to self-reliance.

Firstly, the model suggests that although it is crucial to include the preferences of researchers while formulating the organizational policies yet, prior to any decision making the feasibility in implementing the preferences must be assessed thoroughly (Kumari et al., 2018). Also, for achieving long term success, the laboratories must bridge the gap between the preferences of researchers and the real and rational determinants with respect to (i) the determinants of productivity viz. individual, organizational, and environmental factors; (ii) the extent of researchers' involvement in R&D and/or non-R&D activities; and (iii) the alliance of individual and organizational ambitions pertaining to the expected R&D outputs.

Secondly, the model advises maximizing the involvement of researchers in R&D activities as far as possible. This can be achieved by implementing significant measures like working on R&D projects in the core area of the laboratory and bringing in more R&D projects in the grant-in-aid category (Messeni Petruzzelli, 2012; Masic, 2014). R&D organizations must try to bring changes and implement new processes and policies for making the workplace and work culture fruitful for all (Greiling, 2006; Jindal-Snape and Snape 2006). The authors have explored the factors that influence the R&D productivity of researchers in selected CSIR laboratories. According to the authors, the factor "Man-days Involvement" is an important element that can affect the productivity of researchers. Man-days is a gender-neutral term that refers to the working days (8 hours in a working day) for researchers of CSIR laboratories. The authors conclude that higher the mandays-booking in R&D projects, specifically in GAP (Grant-in-Aid) projects can lead to higher number of Publications (Kumari et al., 2018 and 2020);

Thirdly, the model recommends a balance in the distribution of R&D and non-R&D jobs assigned to the researchers (Moore, 2004; Giddings, 2008; James, 2011). Younger researchers must not be loaded with administrative jobs. Further, job assignments should not be based only on the experience and expertise of the researcher but also on the capability to deliver both R&D and non-R&D outputs. Hence, the laboratories must assess the expertise, competence, and willingness of the researchers, before assigning jobs and responsibilities to them. Organizations must ensure that the non-R&D jobs support the core R&D jobs and do not function in isolation. Nonetheless, crucial non-R&D jobs should not be neglected. The most time-intensive non-R&D jobs like purchase and committee memberships, mentorships etc. must be redistributed/ redesigned by the laboratories to prevent overload on core R&D researchers and enable them to maximize their R&D outputs (Giddings, 2008; James, 2011).

Fourthly, the model emphasizes upon the generation of such R&D outputs that are relevant to the organization and its researchers. Any organizational goal cannot be attained until its workforce collectively puts in efforts towards achieving it. Similarly, the plans of an R&D laboratory cannot be realized until the researchers execute them (Roy and Dhawan, 2002). Hence, it can be concluded that targets for generation of specific R&D outputs must be set in consultation with the researchers, who are the real executers of the project (Roy and Dhawan, 2002; Rana et al., 2013; and Roy and Jay, 2018).

Lastly, the model emphasizes identifying, focusing, and improving upon selecting relevant and significant factors that can impact the productivity of researchers. Hence organizations must identify common factors that can lead to enhancement of productivity of researchers (Strauss, 1966; Reagans and Zuckerman, 2001; Cho and Lee, 2005; Linna et al.

2010; Kumari et al. 2021). Thus, laboratories can ensure a rise in the overall R&D productivity and performance, in the long run.

The productivity model indicates how Indian public sector R&D organizations can attain "self-support" (meeting own expenses) and "self-sustainability" (long term planning to meet own expenses). The need to earn revenues for funding their own expenses rather than depending on government grants can be fulfilled through commercialization of Patents and Technologies (Kumar et al., 2017 and 2018). Besides commercialization, greater participation in R&D, eventually results in utilization of the research manpower in a better way and leads to increased R&D services. The higher the rate of innovation, the better the goodwill of the organization, for its stakeholders. The model of R&D productivity reiterates the findings of the study, viz. focusing on select R&D outputs and factors, implementing select measures for enhancing R&D involvement, redistributing/realigning non-R&D jobs. In this context, a model of productivity has been proposed which can help Indian public funded R&D laboratories to enhance their productivity.

"Take in Figure 5 here"

6.1 Model Validation

The findings of the study were put through the PLS-SEM analysis using proprietary statistical software SmartPLS (trial version). The PLS-SEM model for the R&D Productivity is given in Figure 6. The results of path-analysis showed that the coefficient of determination (R-square) for the model is 0.444 and the R-square adjusted is 0.427. It can be inferred that the constructs of the model together have been able to explain R&D Productivity in 44.4% of the cases in the sample data.

"Take in Figure 6 here"

The output of the PLS-SEM algorithm calculation (Table 10) reflected that the composite validity of the constructs is higher than 0.7 except the two Preferred determinants of R&D Output – Publications and Technologies. The Average variance extracted for all the constructs have values higher than 0.5. The results from the bootstrapping process (Table 11) shows that the constructs 1. Preferred determinants of R&D Outputs (Publications, Awards, Technologies), 2. Influencing Factors (Real) and 3. Significant Measures to enhance R&D Involvement of Researchers, impact R&D Productivity

"Take in Table 10 here"

"Take in Table 11 here"

The predictability of the R&D Productivity Model can be measured by the Q^2 (Table 12).

"Take in Table 12 here"

7.0 Conclusion and Implications

The objectives of this study are to gain new insights and add to the knowledge pertaining to R&D productivity. The study helps identify means and measures for increasing R&D involvement of researchers and enhancing the productivity of researchers, working in Indian public sector R&D laboratories.

Key contributions of the study to theory and practice

The study contributes to the theory by providing a model and its constructs that can help in enhancing productivity of researchers as well as the public sector R&D organizations. Majority of past studies on public sector R&D productivity have focused on the measurement of R&D productivity and suggested the variables relevant for the growth in R&D productivity. This study presents the relevant variables and builds the constructs that aim for the growth of the public sector R&D productivity. The findings would be extremely useful for academicians and practitioners of R&D. Concentrating on relevant R&D outputs that are preferred by the researchers and those that helped in generation of R&D outputs in past, would be the most crucial. The select set of significant factors may be referred by the management of the laboratories to expedite improvement in organizational policies to improve the R&D performance of researchers viz. Balancing between the proportion of various categories of R&D projects. The findings would assist the management of R&D laboratories to explore and include the perspective of their researchers while setting the R&D goals and work profiles. Further, the findings would trigger the redefining, reframing and refining exercises pertaining to the R&D plans as well as effective organizational policies and procedures. This would eventually help researchers in deriving a sense of participation in the decision-making process of the organization, and in turn, organizations would be able to create better work environment for its employees. Individual and organizational performance growth factors can eventually lead towards sustainability of the laboratories as well (Gangopadhyay et al. (2018).

This would further the alignment of employee preferences and organizational objectives. It was further established that prior to setting the organizational goals pertaining to select R&D outputs, an evaluation of competencies must be performed, so that work allocation is done by matching requirements with skills and competencies.

The study identified significant measures for enhancing man-days involvement of researchers in R&D activities. This was followed by exploring the most significant and time-consuming non-R&D jobs, as well as the impact of involvement in such jobs, on the productivity of researchers. The findings emphasize upon redistributing/ restructuring non-R&D jobs in such a manner that younger researchers do not get overburdened with non-R&D activities and can concentrate primarily upon the R&D activities. The study further advocates implementation of measures that would enhance R&D participation of researchers. Again, out of the significant measures only the selective ones should be implemented based upon their suitability of application.

Key implications for the stakeholders of the R&D Organizations

The results of this study justify that the perception of employees and reality can vary. In Indian public funded R&D organizations, usually a top-down approach of decision making is followed. Hence, introducing change is challenging and researcher participation is difficult. Hence, a trust building exercise between the researchers and management is imperative. To increase R&D participation, measures suggested in the study could be implemented. The transformation of preferences into reality requires caution and only the feasible ones should be adopted. The bigger concern for organizations is to correlate the actual with the preferred.

This study also exposes R&D managers the extent of involvement of researchers in non-R&D jobs. The youngsters, who have 4-8 years of experience, show a higher rate of productivity than the seniors. R&D managers need to find a mechanism that lessens the burden on researchers from the overload of S&T management and administrative jobs. This can be done by associating supporting staff with every R&D division/group by hiring research assistants or contract staff. This would enhance the involvement of researchers in core R&D jobs.

8.0 Limitations and Future Direction of Research

The study is limited to CSIR-India laboratories. Inclusion of more public sector laboratories could have provided a wider application to the R&D Productivity Model. Future studies can be taken up by including other R&D laboratories and the model could be validated with the productivity data of R&D laboratories worldwide.

REFERENCES

Abramo, G., D'Angelo, C.A. and Di Costa, F. (2009), "Research collaboration and productivity: Is there correlation?", *Higher Education* , Vol. 57 No. 2, pp. 155-171.

Ahyaruddin, M. and Akbar, R., 2016. The relationship between the use of a performance measurement system, organizational factors, accountability, and the performance of public sector organizations. Journal of indonesian economy and business, 31(1), pp.1-22.

Aguinis, H., Villamor, I. and Gabriel, K.P. (2020), "Understanding employee responses to COVID-19: a behavioral corporate social responsibility perspective", *Management Research,* Vol. 18 No. 4, pp. 421-438. Available online at: https://doi.org/10.1108/MRJIAM-06-2020-1053.

Asiaei, K. and Bontis, N., 2020. Translating knowledge management into performance: the role of performance measurement systems. Management Research Review, 43(1), pp.113-132.

Babu, A.R. and Singh, Y.P. (1998), "Determinants of research productivity", *Scientometrics*, Vol. 43 No. 3, pp. 309-329

Banwet, D.K. and Deshmukh, S.G. (2006), "Balanced scorecard for performance evaluation of R&D organization: A conceptual model", Vol.65 No. 11. Available online at: http://nopr.niscair.res.in/handle/123456789/4952.

Banwet, D.K. and Deshmukh, S.G. (2010), "Modelling the success factors for national R&D organizations: a case of India", *Journal of Modelling in Management,* Vol. 5 No. 2, pp. 158-175. Available online at: https://doi.org/10.1108/17465661011061005.

Breschi, S., Lissoni, F. and Montobbio, F. (2005), "From publishing to patenting: how to become an academic inventor?", In: *Revue d'économie industrielle*, Vol. 110, No. 2e, pp. 75-102. DOI: https://doi.org/10.3406/rei.2005.3073. www.persee.fr/doc/rei_0154-3229_2005_num_110_1_3073

Bonaccorsi, A. and Daraio, C. (2003), "Age effects in scientific productivity", *Scientometrics*, Vol. 58 No. 1, pp. 49-90.

Bolton, M. (2003), "Public sector performance measurement: delivering greater accountability", *Work Study*, Vol. 52 No. 1, pp. 20-24.

Bornmann, L., Mutz, R. and Daniel, H.D., 2008. Are there better indices for evaluation purposes than the h index? A comparison of nine different variants of the h index using data from biomedicine. *Journal of the American Society for Information Science and Technology*, Vol. 59 No. 5, pp. 830-837.

Boyle, R. (2006), "Measuring public sector productivity: lessons from international experience"*, Institute of Public Administration*, Vol. 35.

Bremser, W. G. and Barsky, N. P. (2004), "Utilizing the balanced scorecard for R&D performance measurement", *R&D Management*, Vol. 34 No. 3, pp. 229-238.

Brown, M. G. and Svenson, R. A. (1998), "RTM classic: Measuring R&D productivity", *Research-Technology Management*, Vol. 41 No. 6, pp. 30-35.

Burhan, M. and Jain, S.K. (2015), "Management of intellectual property and technology transfer by public funded research organizations in India: a case of CSIR", *Journal of Intellectual Property Rights*, Vol. 20 No. 6. Available at: http://nopr.niscair.res.in/handle/123456789/33585.

Carayol, N. and Matt, M. (2006), "Individual and collective determinants of academic scientists productivity", *Information Economics and Policy*, Vol. 18 No. 1, pp. 55-72.

Ciurea, M. and Man, M. (2017), "The need to use benchmarking in performance analysis of human resources in the public sector". *Quality-Access to Success*, Vol. 18.

Chaturvedi, S. and Srinivas, K.R. (2012), Science and technology indicators: New issues and challenges, *Current Science*, Vol. 102 No. 12, pp. 1640-1644.

Chiara, S.C.A.L.A.B.R.I.N.O. (2022), "European sustainability competence framework background document (No. JRC130849)", JRC Research Reports , Joint Research Centre (Seville site), Available at: https://ideas.repec.org/p/ipt/ iptwpa/ jrc130849.html

Cho,E. and Lee, M. (2005), "An exploratory study on contingency factors affecting R&D performance measurement", *International Journal of Manpower*, Vol. 26 No. 6, pp. 502-512.

Choi, H.W. and Kang, M.J. (2021), "A Study on the Effect of Satisfaction with R&D Projects on R&D Performance Satisfaction-For SMEs in Jeollanamdo", *International Journal of Internet, Broadcasting and Communication*, Vol. 13 No. 1, pp.11-19.

Coccia, M. (2001), "A basic model for evaluating R&D performance: Theory and application in Italy", *R&D Management*, Vol. 31 No. 4, pp. 453- 464.

Coccia, M. (2017), "Metabolism of Public Research and R&D Management Implications: How Labs Consume Resources", Available online at SSRN: https://ssrn.com/abstract=2951267

Cohen, W. M. Nelson, R. R., and Walsh, J. P. (2002), "Links and impacts: the influence of public research on industrial R&D", *Management Science*, Vol. 48 No. 1, pp. 1-23.

Economic Advisory Council to the Prime Minister (EAC), India has envisioned several targets for the R&D sector for the year 2022, in the report entitled "R&D book for WEB 2019."

Foray, D., Mowery, D.C. and Nelson, R.R. (2012), "Public R&D and social challenges: What lessons from mission R&D programs?", *Research policy*, Vol. 41 No. 10, pp.1697-1702.

Gangopadhyay, D., Roy, S. and Mitra, J. (2018), "Public sector R&D and relative efficiency measurement of global comparators working on similar research streams", *Benchmarking: An International Journal*, Vol. 25 No. 3, pp. 1059-1084. Available online at: https://doi.org/10.1108/BIJ-07-2017-0197.

Rana, G., Goel, A.K. and Rastogi, R. (2013), "Talent management: a paradigm shift in Indian public sector", *Strategic HR Review*.

Giddings, M.C. (2008), "On the process of becoming a great scientist", *PLoS Computational Biology* , Vol. 4 No. 2, p. e33.

Greiling, D. (2006), "Performance measurement: A remedy for increasing *the efficiency of public services?", International Journal of Productivity and Performance Management*, Vol. 55 No. 6, pp. 448.

Griliches, Z. (1979), "Issues in assessing the contribution of research and development to productivity growth*", The Bell Journal of Economics,* Vol. 10 No. 1, pp. 92-116. DOI: 10.2307/3003321

Griliches, Z. Ed. (1984), *"R&D, patents and productivity",* Universit*y of Chicago Press.*

Griliches, Z. *(1994), "Productivity, R&D, and the data constraint, The American Economic Review,* Vol. 84, No. 1, pp. 1-23.

Grossman, G.M. and Helpman, E. (2015), "Globalization and growth", *American Economic Review*, Vol. 105 No. (5), pp.100-104.

Gupta, A.K., Bhojwani, H.R., Koshal, R. and Koshal, M. (2000), "Managing the process of market orientation by publicly funded laboratories: the case of CSIR, India", *R&D Management*, Vol. (30) No. 4, pp. 289-296.

Gupta, R.K. (2005), "Valorization of Intellectual Property from Publicly Funded Organizations: Case Study of the Council of Scientific & Industrial Research (CSIR), India", *Journal of Intellectual Property Rights*, Vol. 10, pp. 406-412.

Hirsch, J. E. (2005), "An index to quantify an individual's scientific research output", *Proceedings of the National academy of Sciences of the United States of America*, pp. 16569-16572.

Hwang, B.Y., Jun, H.J., Chang, M.H. and Kim, D.C. (2017), "A case study on the improvement of institution of High-Risk High-Return R&D in Korea". *Journal of Open Innovation: Technology, Market, and Complexity*, Vol. 3 No. 1, pp. 19.

James, A. (2011), "Too many tasks", *Nature*, Vol. 475 No. 7355, p. 257.

Jääskeläinen, A., and Lönnqvist, A. (2011), "Public service productivity: how to capture outputs?", *International Journal of Public Sector Management*, Vol. 24 No. 4, pp. 289-302.

Jindal-Snape, D. and Snape, J.B. (2006), "Motivation of scientists in a government research institute: scientists' perceptions and the role of management", *Management Decision*, Vol. 44 No. 10, pp. 1325-1343.

Jyoti, Banwet, D. K. and Deshmukh, S. G. (2008), "Evaluating performance of national R&D organizations using integrated DEA-AHP technique", *International Journal of Productivity and Performance Management*, Vol. 57 No. 5, pp. 370-388.

Jyoti, Banwet, D. K., and Deshmukh, S. G. (2010), "Modelling the success factors for national R&D organizations: A case of India", *Journal of Modelling in Management*, Vol. 5 No. 2, pp. 158-175.

Karlsson, M., Trygg, L. and Elfström, B.O. (2004), “Measuring R&D productivity: Complementing the picture by focusing on research activities”, *Technovation*, Vol. 24 No. 3, pp. 179-186.

Kelchtermans, S. and Veugelers, R. (2011), “The great divide in scientific productivity: Why the average scientist does not exist”, *Industrial and Corporate Change*, Vol. 20 No. 1, pp. 295-336.

Kılkış, Ş. (2017), "Sustainable R&D and innovation system comparisons of India, Russia, Mexico and Turkey", Management of Environmental Quality, Vol. 28 No. 3, pp. 315-331. https://doi.org/10.1108/MEQ-05-2015-0075.

Kim, B. and Oh, H. (2002), “An effective R&D performance measurement system: Survey of Korean R&D researchers”, *Omega*, Vol. 30 No. 1, pp. 19-31.

Kim, S. (2015), “Public-Sector Productivity”, Productivity in the Asia-Pacific: Past, Present and Future, *Asian Productivity Organization*, Available online at: http://www.apo-tokyo.org/publications/wp-content/uploads/sites/5/Productivity-in-the-Asia-Pacific_Past-Present-and-Future-2015.pdf#page=272 (eISBN 978-92-833-2438-6 (PDF).

Kumar, N. (2013), “Linking KM Strategy to R&D Performance: An Empirical Study of CSIR R&D Laboratories”, *International Journal of Enhanced Research in Management & Computer Applications*, Vol. 2 Issue 5, pp: 11-19, ISSN: 2319-7471. Available online at: www.erpublications.com.

Kumar, A., Srivastava, A., P Jeevan Kumar, R. and K Tiwari, R. (2017), “Measurement of scientific productivity in R sector: Changing paradigm”, *Recent patents on biotechnology*, Vol. 11 No. 1, pp. 20-31.

Kumar, A., Srivastava, A., Kumar, R.J. and Tiwari, R.K. (2018), “Analyzing Indian research and development organizations: a SWOT analysis”, International Journal of Innovation Science, Vol. 10 No. 3, pp. 298-315. Available online at: https://doi.org/10.1108/IJIS-04-2017-0029

Kumari, B., Sahney, S., Madhukar, A., Chattoraj, I. and Sinni, S. (2015), “Involvement and productivity of research and development workers: A case study of a publicly-funded research laboratory”, *International Journal of Productivity and Performance Management*, Vol. 64 No. 4, pp. 567-589.

Kumari, B., Sahney, S. and Madhukar, A. (2018), “Factors Influencing Productivity of Researchers: A Study of Select Public Sector R&D Laboratories in India”, *International Journal of Global Business and Competitiveness,* Vol. 13 No. 1, pp. 75-98.

Kumari, B., Madhukar, A. and Chattoraj, I. (2020), “E-profiling R&D involvement/earnings of researchers: a G2E tool for performance management at CSIR–NML”, *International Journal of Productivity and Performance Management,* ahead-of-print (ahead-of-print). Available at: http://dx.doi.org/10.1108/ijppm-09-2019-0437.

Kumari, B., Sahney, S. and Madhukar, A. (2021), "Aligning individual and organizational R&D goals for self-sustainability: investigating preferences of researchers in selected CSIR laboratories, India", *International Journal of Productivity and Performance Management,* Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/IJPPM-12-2019-0556.

Koch, J. L. and Steers, R. M. (1978), "Job attachment, satisfaction, and turnover among public sector employees", *Journal of Vocational Behavior*, Vol. 12 No. 1, pp. 119-128.

Landry, R. Traore, .N. and Godin, B. (1996), "An econometric analysis of the effect of collaboration on academic research productivity", *Higher Education*, Vol. 32 No. 3, pp. 283-301.

Linna, P., Pekkola, S., Ukko, J. and Melkas, H. (2010), "Defining and measuring productivity in the public sector: managerial perceptions", *International Journal of Public Sector Management*, Vol. 23 No. 5, pp. 479-499.

Lizarralde, R., Ganzarain, J. and Zubizarreta, M. (2020), "Assessment and Selection of Technologies for the Sustainable Development of an R&D Center", *Sustainability*, Vol. 12 No. 23, pp. 10087. Available online at: https://doi.org/10.3390/su122310087

Masic, I. (2014), "Plagiarism in scientific research and publications and how to prevent it", *Materia socio-médica*, Vol. 26 No. 2, pp.141.

Masic, I. (2014), "Plagiarism in scientific research and publications and how to prevent it", *Materia Socio-Medica*, Vol. 26 No. 2, pp. 141.

Mishra, P.N., Goswami, N.G. and Panda, K.C. (2013), "Impact of grant-in-aid projects at CSIR-National Metallurgical Laboratory, India: A bibliometric study", *SRELS journal of information management*, Vol. *50*, pp.387-412.

Min, B.S. and Smyth, R. (2014), "Corporate governance, globalization and firm productivity", *Journal of World Business*, Vol. 49 No. 3, pp.372-385.

Petruzzelli, A.M., Rotolo, D. and Albino, V. (2012), "The impact of old technologies on innovation: the case of the US biotechnology industry", *Technology Analysis & Strategic Management*, Vol. 24 No. (5), pp.453-466.

Moore, A. (2004), "Just let me be a scientist", *EMBO Reports*, Vol. 5 No. 7, pp. 660-662.

Obembe, O.B. (2012), "Determinants of scientific productivity among Nigerian university academics", *Indian journal of science and technology*, Vol. 5 No. 2, pp.2155-2164.

Pal, J.K. and Sarkar, S. (2020), "Evaluation of Institutional Research Productivity", *DESIDOC Journal of Library & Information Technology*, Vol. 40, No. 1, pp. 406-417. Available online at: DOI: 10.14429/djlit.40.1.14804.

Pappas, R. A. and Remer, D. S. (1985), "Measuring R&D productivity", *Research Management*, Vol. 28 No. 3, pp. 15-22.

Phusavat, K. (2013), "Productivity Management in an Organization: Measurement and Analysis", *ToKnowPress Monographs.* Available online at: http://www.toknowpress.net/ISBN/978-961-6914-05-5.pdf

Prabhakar, G.P., 2011. An interview with former CSIR Director-General Raghunath Anant Mashelkar. *International Journal of Public Sector Management*, Vol. 24 No. 5. Available online at: https://doi.org/10.1108/ijpsm.2011.04224eaa.001.

Pritchard, R. D. (1995), "Productivity measurement and improvement: Organizational case studies", *Greenwood Publishing Group.*

Post, C., DiTomaso, N., Farris, G.F. and Cordero, R. (2009), "Work-family conflict and turnover intentions among scientists and engineers working in R&D", *Journal of Business and Psychology*, Vol. 24 No. 1, pp. 19-32.

Ramírez, Y.W. and Nembhard, D.A. (2004), "Measuring knowledge worker productivity: a taxonomy", *Journal of Intellectual Capital*, Vol. 5 No. 4, pp. 602-628.

Rana, G., Goel, A.K. and Rastogi, R. (2013), "Talent management: a paradigm shift in Indian public sector", *Strategic HR Review*, Vol. 12 No. 4, pp. 197-202.

Rayasam, G.V. and Mande, S.C. (2020), "Role of S&T organisations in mitigation of Covid-19: CSIR as a case study", *Indian Chemical Engineer*, Vol. 62 No. 4, 333-342, DOI: https://doi.org/10.1080/00194506.2020.1832588.

Reagans, R. and Zuckerman, E.W. (2001), "Networks, diversity, and productivity: the social capital of corporate R&D teams", *Organization Science*, Vol. 12 No. 4, pp. 502-517.

Robledo, I.C., Peterson, D.R. and Mumford, M.D. (2012), "Leadership of scientists and engineers: A three-vector model", *Journal of Organizational Behavior*, Vol. 33 No. 1, pp.140-147.

Rotolo, D. and Messeni Petruzzelli, A. (2013), "When does centrality matter? Scientific productivity and the moderating role of research specialization and cross-community ties", *Journal of Organizational Behavior*, Vol. 34 No. 5, pp. 648-670.

Roy, S. and Dhawan, S.K. (2002), "Preliminary pointers towards improving the work environment in CSIR laboratories: Remarks from an empirical study", *Current Science*, Vol. 82 No. 3, pp.269-272.

Roy, S., Mitra, J. and Debnath, R.M. (2013), "Ranking R&D institutions of India: an application of DEA", *International Journal of Business Development and Research*, Vol. 1 No. 2, pp. 49-66. Available online at: http://bus.ku.ac.th/journal/files/IJBDR_Volume1_Issue2_2013.pdf#page=56.

Roy, S. and Mitra, J. (2018), "Tacit and explicit knowledge management and assessment of quality performance of public R&D in emerging economies", *Journal of Organizational Change Management*, Vol. 31 No. 1, pp. 188-214. Available online at: https://doi.org/10.1108/JOCM-06-2017-0236.

Roy, S. and Mitra, J. (2018), "Assessment of quality performance of public R&D in India and the strategic role of knowledge management: evidence from a longitudinal study", Available online at: http://liee.ntua.gr/wp-content/uploads/2018/02/739-Assessment-of-Quality-Performance-of-Public-RD-in-India-and-the-Strategic-Role-of-Knowledge-Management-.pdf.

Saraf, C.U. (2014), “Elements of managing transfer of technology from laboratory to industry: Technology Transfer Management (TTM)”, *Journal of Scientific & Industrial Research*, Vol. 73 pp. 704-710

Scherer, F. M. (1982), “Inter-industry technology flows and productivity growth", *The review of economics and statistics*, Vol. 64 No. 4, pp. 627-634, DOI: 10.2307/1923947.

Dhawan, S.K., Roy, S. and Kumar, S. (2002),”Organizational energy: an empirical study in Indian R&D laboratories”, *R&D Management*, Vol. 32 No. 5, pp.397-408.

Sharma, N.D., Kumar, S., Senguttuvan, T.D., Sharma, A., Pulikkotil, J.T., Rao, S.R., Chadha, D., Singh, N., Sengar, A. and Aswal, D.K. (2020), “CSIR-NPL: Growth Driver for Effective Implementation of National Policies”, In *Metrology for Inclusive Growth of India,* pp. 1029-1076. Springer, Singapore. Available online at: doi: 10.1007/978-981-15-8872-3_21, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7979558/.

Strauss, P.S. (1966), “Psychology of the scientist: XIX. job satisfaction and productivity of engineers and scientists”, *Perceptual and Motor Skills* , Vol. 23 No. 2, pp. 471-476.

Tangen, S. (2002, December), “Understanding the concept of productivity”, *in Proceedings of the 7th Asia-Pacific Industrial Engineering and Management Systems Conference, Taipei,* pp. 18-20.

Tangen, S. (2005), “Demystifying productivity and performance”, *International Journal of Productivity and performance management*, Vol. 54 No. 1, pp. 34-46.

Tijssen, R.J. and Winnink, J.J. (2018), “Capturing ‘R&D excellence’: Indicators, international statistics, and innovative universities”, *Scientometrics*, Vol. 11 No. 2, pp. 687-699.

Thornhill, S. (2006), “Knowledge, innovation and firm performance in high-and low-technology regimes”, *Journal of business venturing*, Vol. 21 No. 5, pp. 687-703.

Turner, L. and Mairesseb. J. (2005), “Individual Productivity Differences in Public Research: How Important are Non-Individual Determinants?*”*, An Econometric Study of French Physicists’ Publications and Citations, (1986-1997) , Centre National de la Recherche Scientifique, Paris.

Uttam, S. and Venugopal, P. (2008), “Assessment of benefits from sponsored research in publically funded organizations: A semi-empirical model”, *Research Management Review*, Vol. 16 No. 1, pp.57-68.

White, C.S., James, K., Burke, L.A. and Allen, R.S. (2012), “What makes a ‘research star’? Factors influencing the research productivity of business faculty”, *International Journal of Productivity and Performance Management*, Vol. 61 No. 6, pp. 584-602.

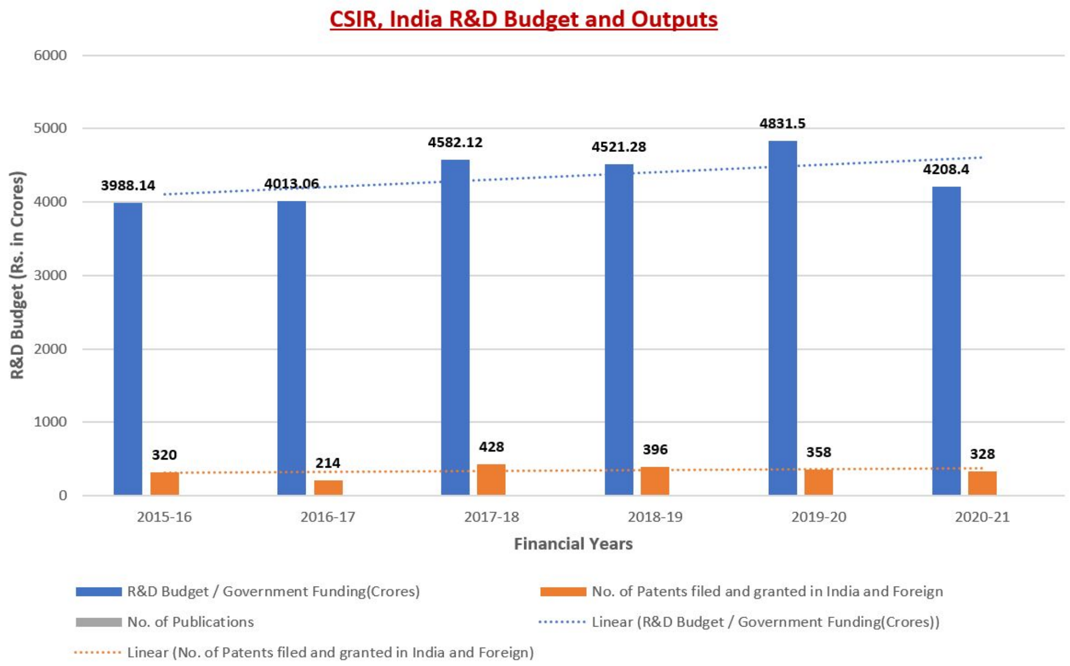

Figure 1: CSIR-India: Trend of R&D Funding & Outputs

[Source: https://patestate.com/ as on 19/5/21, https://csir.res.in]

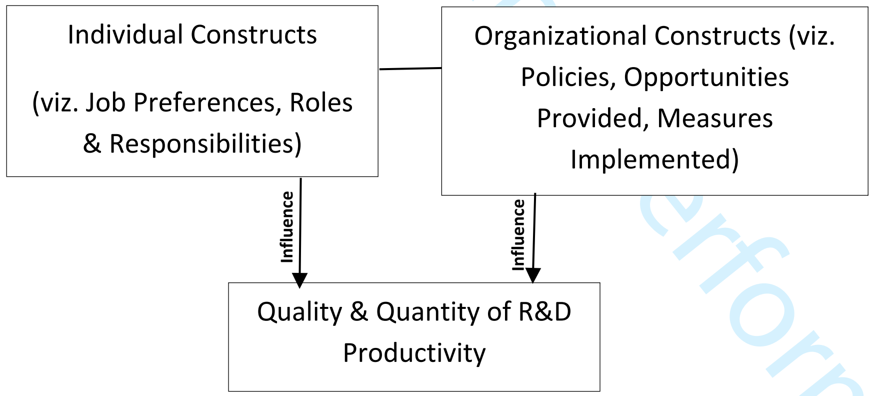

Figure 2: Conceptual Model- Individual and Organizational Constructs Influencing R&D Productivity

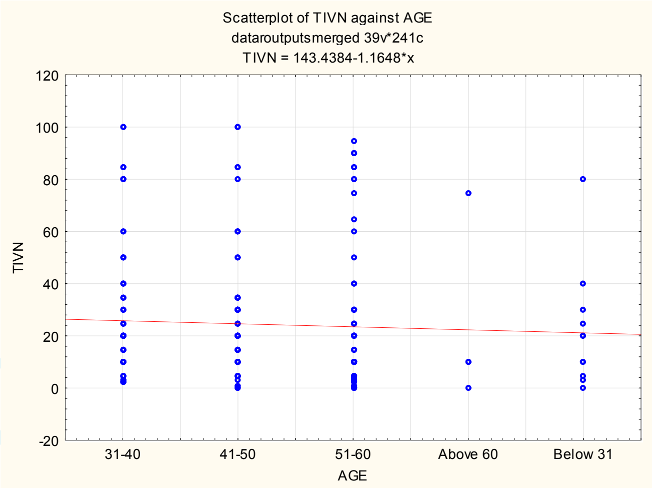

Figure 3: Scatter plot of Total Man-days Involvement in Non-R&D Activities (TIVN) in researchers of different age groups

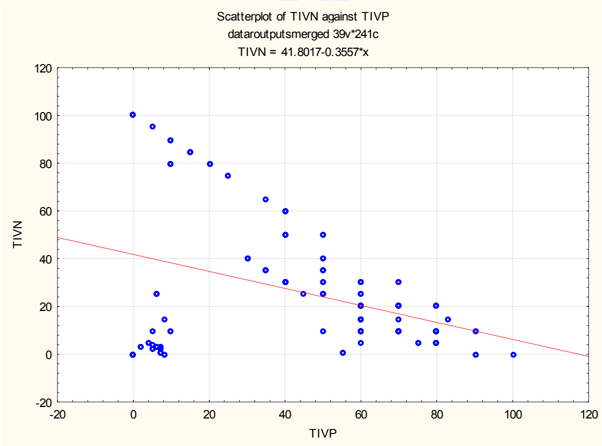

Figure 4: Scatter plot of inversely related Total Man-days Involvement in R&D Projects (TIVP) and Total Man-days Involvement in Non-R&D Activities (TIVN)

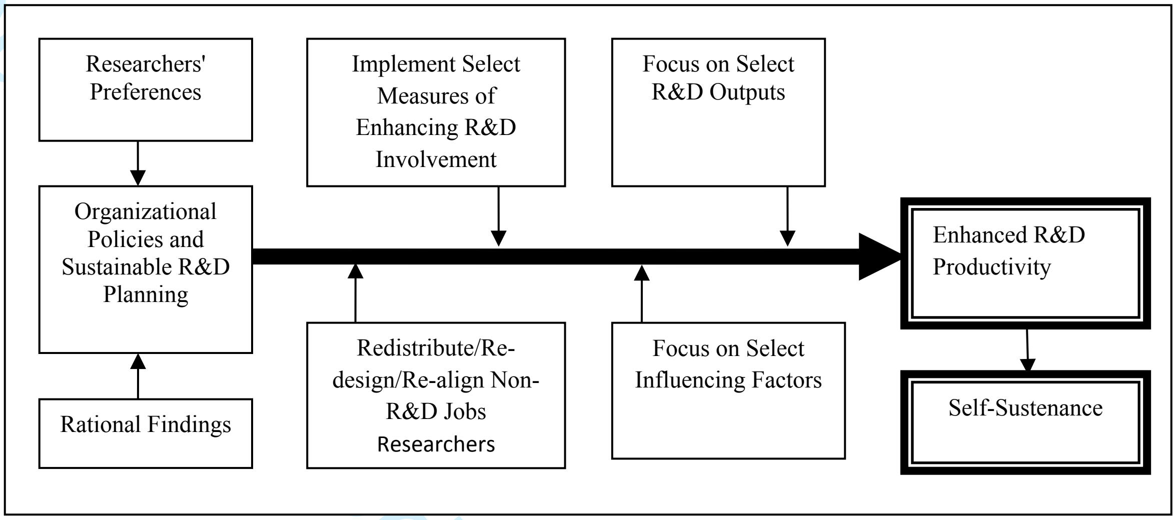

Figure 5: Model of R&D Productivity

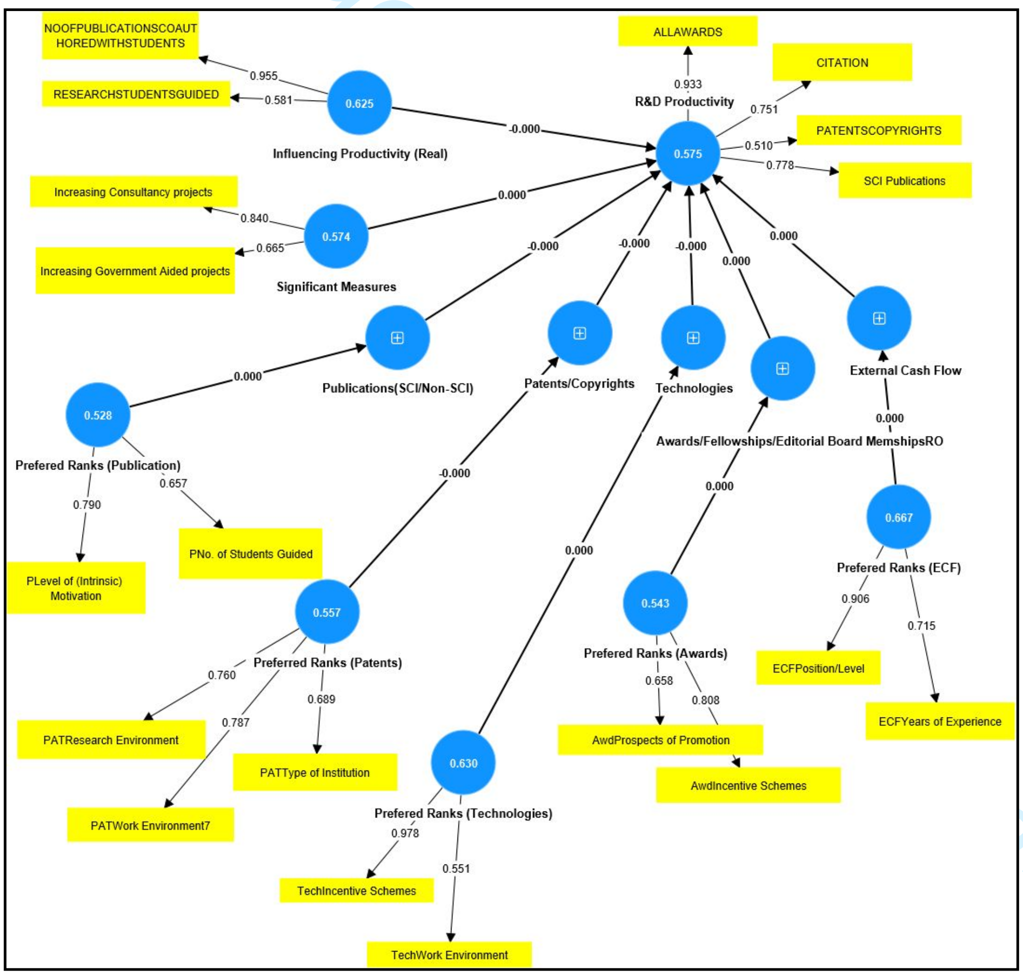

Figure 6: SEM-PLS Model

Table 1: Top Ten Indian Research Institution Rank [India and World]

Scimago Institutions Rankings 2022* [Based on list of publications in Scopus database]		
Institute (Government)	**Rank (World)**	**Rank (India)**
Council of Scientific and Industrial Research	186	1
Indian Council of Agricultural Research	366	2
Institute of Microbial Technology	367	3
National Institute of Plant Genome Research	370	4
International Centre for Genetic Engineering and Biotechnology, New Delhi	371	5
Tata Memorial Centre	375	6
Inter-University Centre for Astronomy and Astrophysics	392	7
Centre for Cellular and Molecular Biology Indian Institute of Science Education and Research, Pune	397	8
Institute of Genomics and Integrative Biology	404	9
Aryabhatta Research Institute of Observational Sciences	411	10
Nature Index 2022** [Based on count of Research Outputs in 82 Nature Journals during December 2019- November 2021]		
Institution (Government)	**Rank (World)**	**Rank (India)**
Council of Scientific and Industrial Research (CSIR)	21	1
Tata Institute of Fundamental Research (TIFR)	32	2
India Department of Space (DOS)	71	3
National Institute of Science Education and Research (NISER)	74	4
Harish-Chandra Research Institute (HRI)	76	5
India Ministry of Science and Technology	91	6
S. N. Bose National Centre for Basic Sciences (SNBNCBS)	93	7
Department of Atomic Energy (DAE)	99	8
Institute of Mathematical Sciences (IMSc)	103	9
Saha Institute of Nuclear Physics (SINP)	110	10
*Ranking Web of Research Centers (2019)*** [Based on Google Scholar Citation]*		
Institution (Government)	**Rank (World)**	**Rank (India)**
Bhabha Atomic Research Centre	241	1
Indian Council of Agricultural Research	272	2
Indian Space Research Organization	363	3
Council of Scientific and Industrial Research	378	4
Jawaharlal Nehru Centre for Advanced Scientific Research	451	5
Saha Institute of Nuclear Physics	517	6
Indian Association for the Cultivation of Science	535	7
National Institute of Technology Calicut	552	8
Institute of Mathematical Sciences	620	9
Defence Research and Development Organisation	631	10
**Source: (Schimago Rankings for institutions on research, innovation & societal outputs 2022) https://www.scimagoir.com/rankings.php?sector=Government&ranking=Research* ***Source: Nature Index Year 2022 (A table of institutions ordered by research outputs (Article Publications) of 2021) https://www.nature.com/nature-index/institution-outputs/generate/all/countries-India/government*		

****Source: Ranking Web of Research Centers 2019 based on the Journal papers' Presence, Visibility, Transparency And Excellence; https://research.webometrics.info/en/Asia/ India (As on 06/02/2023)*

Table 2: SWOT Analysis of CSIR-Laboratories (Source: Kumar et al. (2017)

	R&D Outputs	Significant Influencing Factors
1	**Strength**	Intellectual capital, Diverse research areas, Robust state-of-the-art infrastructure, Strong research and global recognition, Strong research grants and government funding;
2	**Weakness**	Under-utilization of laboratory resources, Identifying the research priorities, Emphasis on international linkages and collaborations, Low provision of incentivizing and rewarding innovators and Low commercialization of patents on global scale;
3	**Opportunity**	Reorganize scientific manpower vis-a vis mandate, Prioritization of research and Fast pace of commercialization of IP;
4	**Threats**	Intellectual vacuum, Under-utilization and judicious use of infrastructure and Loss of patented, but uncommercialized technologies;

1 Table 3 (a): Source-Context Table (R&D Outputs)
2 Table 3 (b): Source-Context Table (Factors Influencing the R&D Outputs)
3 Table 3(c):Source-Context Table (Items)

Table 3 (a): Source-Context Table (R&D Outputs)

R&D Outputs	Authors	Definition/Context
Publications (SCI/Non-SCI)	- Mauleón and Bordons, (2006)	The authors have conducted a gender-based comparative analysis of productivity pertaining to the scientists of Spanish Council for Scientific Research (CSIC), and have examined productivity indicators like number of publications, percentage of documents in top journals and publication practices. The authors observe that women were less productive than men, but an insignificant difference in their productivity has been found when the influence of 'professional category' and 'age' are analysed.
Publications (SCI/Non-SCI)	- Jyoti et al. (2008)	The authors have compared the performance of national R&D laboratories of Council of Scientific and Industrial Research (CSIR), and have considered a number of output variables for making comparisons. The output variables include paper publications, patents, external cash flow

		generated, new product/process/technology, Ph. Ds awarded and awards received.
Publications (SCI/Non-SCI)	- Prathap (2013)	A high amount of R&D output 'publication' has been considered one of the prime indicators of productivity of the best performing public funded laboratories in India.
Patents/ Copyrights	- Jyoti et al. (2008)	The authors have compared the performance of national R&D laboratories of Council of Scientific and Industrial Research (CSIR), and have considered a number of output variables for making comparisons. including patents.
Patents/ Copyrights	- Prathap (2013)	A high amount of R&D output 'patents/copyrights' has been considered as one of the prime indicators of productivity of the best performing public funded laboratories in India.
Technologies	- Jyoti et al. (2008)	The authors have compared the performance of national R&D laboratories of Council of Scientific and Industrial Research (CSIR), and have considered a number of output variables for making comparisons including patents, external cash flow generated, new product/process/technology, Ph. Ds awarded and awards received.
Awards/Fellowships/Editorial Board Memberships	- Jyoti et al. (2008)	The authors have compared the performance of national R&D laboratories of Council of Scientific and Industrial Research (CSIR), and have considered a number of output variables for making comparisons including awards received.
External Cash Flow	- Jyoti et al. (2008)	The authors have compared the performance of national R&D laboratories of Council of Scientific and Industrial Research (CSIR), and have considered a number of output variables for making comparisons including external cash flow generated.
Citation	- Turner and Mairesseb, (2005)	The authors have considered the 'citation of papers' as a R&D output, and have found positive impact of 'age' and 'promotion' on 'citation of papers'. The authors have also found a "life cycle effect" which is based upon the citation of papers of retired researchers.
Citation	- Dias (2012)	The author has considered 'h-index' as a means of measuring productivity with respect to the total number of papers published by a researcher.

Table 3 (b): Source-Context Table (Factors Influencing the R&D Outputs)

Influencing Factors	**Authors**	**Type of Influencing Factors**	**Definition/Context**
Access to literature	Babu and Singh (1998)	Organizational	The authors have compared the impact of individual and institutional factors on R&D productivity, and found that institutional factors like "resource adequacy" and "access to literature" impact R&D productivity positively.
Professional commitment	Babu and	Individual	Individual factors have a greater impact on the R&D productivity of researchers than the institutional

	Singh (1998)		factors. These factors are "persistence", "initiative", "intelligence", "creativity", "learning capability", "concern for advancement" and "professional commitment".
Industrial collaboration	Landry et. al. (1996)	Environmental	The "collaboration" between researchers and industry has found to be more productive than "collaboration" between researchers and their peers or researchers and government institutions.
Industrial collaboration	Abramo et al. (2009)	Environmental	The interdisciplinary scientific disciplines are impacted by "collaboration" positively.
Organizational infrastructure	Babu and Singh (1998)	Organizational	A comparison of the impact of individual and institutional factors shows that institutional factors like "resource adequacy" and "access to literature" impact R&D productivity. In German research groups "human resources" are the weakest factor, and "decreasing education quality" and "inadequacy of researchers" are prime reasons behind it.
Organizational infrastructure	Wang et al. (2006)	Organizational	It was found for the German researchers, the "human resources" is the weakest factor and "decreasing education quality" and "inadequacy of researchers" is the prime reasons behind it.
Customer satisfaction	Kim and Oh (2002)	Organizational	A study of 1200 Korean researchers about an effective performance R&D evaluation was conducted. According to the authors the criteria groups "Market-oriented", "R&D project-specific", "R&D researchers' technological attributes" and "R&D researchers' behavioral attributes" should be considered for R&D performance evaluation.
Industrial growth rate	Karlsson et al. (2004)	Environmental	The application of a productivity measuring approach has been advocated by the authors; the approach is such that can handle external factors like "changing customer demands" and "developments in the market".
Economy of country	Karlsson et al. (2004)	Environmental	The application of a productivity measuring approach has been advocated by the authors; the approach is such that can handle external factors like "changing customer demands" and "developments in the market".
Quality of service	Ramírez and Nembhard (2004)	Organizational	A review of literature on R&D productivity measurement for sixty years reveals an absence of a generically-applicable model on productivity. A measurement for "knowledge workers" had been evolved. "Quality" is the most frequently used variable for productivity measurement.
Quality of service	Oeij et al. (2011)		The authors have discussed the Q4 - model of researchers' productivity. The quantity and quality help improve "organizational effectiveness" and this effectiveness can enhance the productivity of

			researchers. According to the authors, "quality" is the most frequently used variable for productivity measurement in last sixty years.
Incentive schemes	Jindal-Snape and Snape (2006)	Organizational	The removal of 'negative factors' is treated as more important for improving productivity than adding new 'incentives' in a government set up.
Developments in market	Karlsson et al. (2004)	Environmental	The authors advocate the application of a productivity measuring approach that can handle external factors like "changing customer demands" and "developments in the market".
Prospects of promotion	Jindal-Snape and Snape (2006)	Organizational	The removal of 'negative factors' is treated as more important for improving productivity than adding new 'incentives' in a government set up.
Supervisor support	Ohly et al. (2006)	Organizational	The authors have examined the determinants "routinization", "job control", "job complexity", "time pressure" and "supervisor support" and found that "routinization" had a positive impact on the "creativity" of outputs of a researcher.
Level of (intrinsic) motivation	Jindal-Snape and Snape (2006)	Individual	The factors affecting the motivation of researchers of government organizations for improving their R&D productivity was analyzed, and it was found that 'intrinsic motivation' positively influences productivity.
Organizational infrastructure	Wang et al (.2006)	Organizational	With respect to the German research groups, the authors conclude that "human resources" is the weakest factor and "decreasing education quality" and "inadequacy of researchers" are the prime reasons behind it.
Eminence of researcher	Vinkler (2007)	Environmental	The authors suggest that the "eminence of a scientist" by means of one's "h-index" must be verified from as many web sources as possible.
Eminence of researcher	Jacso (2008)	Environmental	It was recommended that the correctness of the h-index must be verified from as many web sources as possible and while determining the "h-index", the limitations of these databases must also be kept in view.
Years of experience	Moore (2004)	Individual	The concern about the position of highly "experienced, highly qualified post-docs" being treated as non-valuable and not being offered proportionate remuneration equivalent to their qualification is dealt with by the author.
Funding	Underwood (2009)	Organizational	Governmental funding agencies and bodies must control the type of research being taken up by the researchers.

Family environment	Post et al. (2009)	Individual	Professional and environmental factors like "work interference with family" and "family interference with work" also influence a researcher's decision for leaving R&D and joining non R&D jobs.
Work Environment	Post et al. (2009)	Organizational	Professional and environmental factors like "work interference with family" and "family interference with work" also influence a researcher's decision for leaving R&D and joining non R&D jobs.
Work Environment	James (2011)	Organizational	Administrative, teaching and research jobs should be redistributed to many, rather than the same researcher doing all the jobs.
Research environment	James (2011)	Organizational	Administrative, teaching and research jobs should be redistributed to many, rather than the same researcher doing all the jobs.
Educational background	Krell (2012)	Individual	The journal impact factor must be considered in association with other variables also, as these determinants influence the number of citations highly.
Research area/Area of publication	Rotolo and Messeni Petruzzelli (2012)	Individual	There exists an "inverted U-shaped relationship" between "centrality" and "productivity".
Research area/Area of publication	Obembe (2012)	Individual	The determinant 'field of research' has a significant effect on researchers' productivity and the fields of research like 'chemistry', "bio-chemistry", 'pharmacy' and "plant science" were found to be more productive than the fields of "physics", "mathematics" and "electronics".
	Obembe (2012)	Individual	The determinant 'field of research' has a significant effect on researchers' productivity and the fields of research like 'chemistry', "bio-chemistry", 'pharmacy' and "plant science" were found to be more productive than the fields of "physics", "mathematics" and "electronics".
Publications (SCI/Non-SCI)	Prathap (2013)	Individual	These variables are prime indicators of productivity of the best performing public funded laboratories laboratory.

Table 3 (c): Source-Context Table (Items)

Item	Authors	Definition/Context
Access to literature (Hard Copy/ Soft Copy)	Babu and Singh (1998)	The authors have compared the impact of individual and institutional factors and found that institutional factors like "resource adequacy" and "access to literature", impact R&D productivity positively.
Date of birth/Age	Bonaccorsi and Daraio (2003)	Productivity declines with the increasing age of researchers.

Date of birth/Age	Skirbekk (2004)	The authors have found an inverted U-shaped profile of productivity for the age group of around 50 years.
Date of birth/Age	Turner and Mairesseb (2005)	The authors have found a positive impact of 'age' and 'promotion' on productivity. Based upon the citation of papers of retired researchers, the authors have also found a "life cycle effect"
Date of birth/Age	Skirbekk (2008)	The author have found that 'age' had a positive impact on productivity, especially, in those jobs that required the skills and experience of elderly people.
Marital status, Having children, Spouse working	Stack (2004)	The author has found that "gender" has a significant effect on productivity. He also concludes that women in permanent positions with young children were higher in productivity as compared to women in temporary positions with young children.
Marital status, Having children, Spouse working	Mauleón and Bordons (2006)	The authors have observed that women were less productive than men but insignificant differences between men and women were found when the influence of "professional category" and 'age' were analysed.
Marital status, Having children, Spouse working	Von (2011)	The authors observe that being in the same "age" and "position", men had a higher average score of "public outreach and engagement activities" as compared to women.
H-Index	Vinkler (2007)	The correctness of the h-index must be verified from as many web sources as possible. While determining the "h-index", the limitations of the databases must also be kept in view.
Research environment	Post et al., 2009	Administrative, teaching and research jobs must be redistributed to more people.
Time pressure	Post et al., 2009	Professional and environmental factors like "work overload", "weekly working hours", "work dissatisfaction" influence a researcher's decision for leaving R&D and joining non R&D jobs.
Subject: Academic qualification	Krell (2012)	ThejJournal impact factor must be considered in association of other variables as these determinants influence the number of citations highly.
Core area of research	Obembe (2012)	The determinant 'field of research' has a significant effect on researchers' productivity and the fields of research like 'chemistry', "bio-chemistry", 'pharmacy' and "plant science" were found to be more productive than the fields of "physics", "mathematics" and "electronics".
No. of students guided	White et al. (2012)	The effect of "situational" variables on productivity was assessed by the authors and it was found that variables like "doctoral

(Research students)		student support", "summer stipends" and "other research grants" may help in getting resources for conducting research.
No. of publications coauthored with students(Research Students)	White et al. (2012)	The effect of "situational" variables on productivity was assessed by the authors and it was found that variables like "doctoral student support", "summer stipends" and "other research grants" may help in getting resources for conducting research.
No. of publications (SCI)/ (Non-SCI)	Prathap (2013)	According to the author, these variables are considered to be the prime indicators of productivity of the best performing public funded laboratories laboratory.
No. of patents	Prathap (2013)	According to the author, these variables are considered to be the prime indicators of productivity of the best performing public funded laboratories laboratory.

Table 4: Significant Influencing Factors

	R&D Outputs	Significant Influencing Factors
1	**Awards/Fellowships/Editorial Board Memberships**	Age and Highest Impact Factor Publication (Journal Publication),
2	**Patents and Copyrights**	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
3	**Highest Citations Received (Journal Publication)**	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,
4	**Publication**	Age, 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)

5	**External Cash Flow**	-
6	**Technologies**	-

Table 5: Significant Influencing Factors (Preferences)

#	R&D Outputs in Order of Preference by Researchers	Influencing Factors in Order of Preference by Researchers
1	**External Cash Flow**	*Quality of Service, Customer Satisfaction, Organizational Infrastructure, Collaboration with Industry, Industry Contacts Developed, Industrial Growth Rate and Professional Commitment*
2	**Awards/Fellowships/Editorial Board Memberships**	*Innovative Work Profile in the Same Research Area, Professional Commitment, Willingness of Organization, No. of Publications, Association with Relevant Organization, Funding and Eminence in the Field*
3	**Highest Citations Received**	*Eminence of Researcher, High Impact Factor of Journal, Innovativeness/Novelty of Research Work, Research Area and High Impact Research Work*
4	**Patents/Copyrights**	*Professional Commitment, Research Environment, Industrial Application, No. of Research Projects, Work Environment and Innovativeness of Idea/Novelty*
5	**Technologies**	*Industrial Collaboration, Organizational Infrastructure, Professional Commitment, Developments in Market, Customer Interfacing, Work Environment and Innovativeness of Idea/Novelty*
6	**Publications(SCI/Non-SCI)**	*Research Area/Area of Publication, Educational Background, No. of Research Projects, Access of Literature, Communication Skill and Work Environment*

Table 6: Measures for Enhancing R&D Involvement of Researchers

Source	Measures	Context
Breschi et al. (2005)	Increasing industry collaborative projects Increasing consultancy projects	The authors have studied the effect of the determinant scientific collaboration with industry on the patents, and conclude that collaboration increases the number of co-authored papers published as well as earning of joint patents.
Jindal-Snape and Snape (2006) Kelchtermans and Veugelers (2011)	Providing incentives for increased participation Linking project participation and R&D outputs to promotions	The removal of demotivating factors like lack of feedback from management, difficulty in collaborating with colleagues, and constant review and change is considered important, for improving productivity of researchers in a government set up. Incentive factors like promotion record and access to research resources help in achieving high productivity of researchers.

Post et al. (2009)	Concentrating on making better work environment	The intention of a researcher for leaving R&D, and joining non-R&D is largely affected by the work dissatisfaction.
Rotolo and Messeni (2013)	Letting researchers bring and work in their own core area of research apart from lab mandate	The existence of an inverted U-shaped relationship between centrality and productivity, was found due to the limiting factor of research specialization of researchers.
Masic (2014)	Providing technical training in the major research area of organization and encourage researchers to work in major research area of organization Providing motivational training to researcher for participation in increased number of projects	The author has conducted a study on prevention of plagiarism in scientific research and publications, and advised that organizations must make a rule book of good practice and make it obligatory for all researchers to follow the same while publishing any kind of R&D work. Along with this, he also advises that researchers willing to be renowned in their fields must learn the rules on preventing plagiarisms, and must cite other researchers work appropriately.
Experts View	Increasing the total number of projects	-
	Increasing the number of projects in organizations major core area	-
	Increasing government aided projects	-
	Increasing sponsored projects	-
	Increasing network/mega aided projects	-
	Setting targets for association in a minimum number of projects	-

Table 7: Weighted Average Scores of Measures

Measures	Total Weighted Score	Weighted Average Score	Percentage Weighted Average Score
Increasing industry collaborative projects	519	35	14.46
Increasing sponsored projects	482	32	13.22

Increasing the number of projects in organizations major core area	407	27	11.16
Linking project participation and R&D outputs to promotions	357	24	9.92
Increasing government aided projects	347	23	9.5
Providing incentives for increased participation	287	19	7.85
Concentrating on making better work environment	267	18	7.44
Providing motivational training to researcher for participation in increased number of projects	240	16	6.61
Providing technical training in the major research area of organization and encourage researchers to work in major research area of organization	222	15	6.2
Increasing consultancy projects	204	14	5.79
Increasing network/mega aided projects	193	13	5.37
Increasing the total number of projects	174	12	4.96
Letting researchers bring and work in their own core area of research apart from lab mandate	165	11	4.55
Setting targets for association in a minimum number of projects	150	10	4.13
Others	38	3	1.24

Table 8: Select Non-R&D Jobs

Source	Non-R&D Jobs	Context
Giddings (2008)	- Committee Memberships/Meetings - Purchase	According to the author, a researcher must not be overloaded with the non-R&D jobs, as else he would get away from the R&D jobs. The author concludes that a researcher must learn to say no to such overloading, as saying no is an important aspect of a researchers personality for becoming a great scientist.
James (2011)	- Mentorship/Students Guided	The job profile of researchers includes not only core R&D jobs but several non-R&D jobs viz. academic and administrative. In Indian R&D laboratories that work in sharing mode (resources sharing in multiple projects), it is problematic to

		balance the ratio of experts to projects, for any of the specific research domains. -One-to-many relationship may exist between a researcher and his assignments which if, not managed properly may affect his productivity in several adverse ways.
Experts View	- Organization of Events	-
	- Customer Service	-
	- R&D Support	Examples: Memorandum of Understanding/Service Agreements/Finance/Database Management/Network Management/E-Tendering
	- Client Interaction (Business Development)	-
	- Any Other	-

Table 9: Frequency Distribution of Non-R&D Jobs

Non-R&D Jobs	Frequency	Percentage
Committee Memberships/Meetings	163	21
Mentorship/Students Guided	151	19
R&D Support	100	13
Purchase	100	13
Organization of Events	97	13
Client Interaction (Business Development)	93	12
Customer Service	51	6
Any Other	21	3

Table 10: Internal Consistency Reliability and Convergent Validity of Model (PLS-SEM)

	Composite reliability (rho_c)	Average variance

		extracted (AVE)
Preferred determinants of R&D Output - Publications	0.699	0.537
Preferred determinants of R&D Output - Awards	0.784	0.552
Preferred determinants of R&D Output - ECF	0.769	0.526
Preferred determinants of R&D Output - Technologies	0.697	0.535
Preferred determinants of R&D Output - Patents	0.746	0.515
Influencing Factors (Real)	0.762	0.627
Significant Measures	0.713	0.57
R&D Productivity	0.835	0.569

Table 11: The Result from Bootstrapping Process

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
Preferred determinants of R&D Output - Publications -> R&D Productivity	0.2	0.189	0.069	2.889	0.004
Preferred determinants of R&D Output - Awards -> R&D Productivity	0.183	0.17	0.046	4.009	0
Preferred determinants of R&D Output - ECF -> R&D Productivity	-0.007	0.004	0.051	0.129	0.897
Preferred determinants of R&D Output - Technologies -> R&D Productivity	0.137	0.141	0.062	2.212	0.027
Preferred determinants of R&D Output - Patents -> R&D Productivity	-0.05	-0.018	0.054	0.919	0.358
Influencing Factors (Real)-> R&D Productivity	0.498	0.5	0.052	9.662	0
Significant Measures -> R&D Productivity	0.103	0.103	0.048	2.155	0.031

Table 12: Predictability of the Productivity Model

	Q^2predict	PLS-SEM_RMSE	PLS-SEM_MAE	LM_RMSE	LM_MAE
Awards	0.226	59.982	40.527	60.347	41.15
Citation	0.047	53.776	34.371	53.476	34.495
Patents	0.039	7.829	3.437	7.851	3.302
Publications	0.435	16.715	11.437	16.696	11.75