INNOVATION BY HIGHER ACADEMIC TECHNICAL INSTITUTIONS AND ITS DETERMINANTS: AN EMPIRICAL STUDY OF INDIAN ACADEMIA

AKRITI JAIN

DEPARTMENT OF MANAGEMENT STUDIES
INDIAN INSTITUTE OF TECHNOLOGY DELHI
HAUZ KHAS, NEW DELHI – 110016

JANUARY 2019

INNOVATION BY HIGHER ACADEMIC TECHNICAL INSTITUTIONS AND ITS DETERMINANTS: AN EMPIRICAL STUDY OF INDIAN ACADEMIA

by

AKRITI JAIN

Department of Management Studies

Submitted

In fulfillment of the requirement of the degree of

DOCTOR OF PHILOSOPHY

to the

INDIAN INSTITUTE OF TECHNOLOGY DELHI

January 2019

DEDICATED TO SHRI ADI SHAKTI AND MY BELOVED GRANDMOTHER

CERTIFICATE

The thesis entitled '**Innovation by Higher Academic Technical Institutions and its Determinants: An Empirical Study of Indian Academia**', being submitted by **Ms. Akriti Jain** to the Indian Institute of Technology Delhi, for the award of the degree of "**Doctor Of Philosophy (Ph. D.)**" is a record of *bona fide* research work carried out by her. She has worked under our guidance and supervision and has fulfilled the requirements for submission of this thesis, which has attained the standard required for Ph. D. degree of this institute. The results presented in this thesis have not been submitted in part or in full to any other university or institute for award of any degree or diploma.

Date:
Place:

Dr. Vigneswara Ilavarasan
Associate Professor
Department of Management Studies
Indian Institute of Technology, Delhi
Hauz Khas, New Delhi
India - 110016

Dr. Ruchi Sharma
Associate Professor
Humanities and Social Science
Indian Institute of Technology, Indore
Simrol, Madhya Pradesh
India – 453552

ABSTRACT

The present thesis undertakes four studies on innovation by the public funded academic research institutions in a lower-middle-income country i.e. India. The first study focuses on developing a multidimensional conceptual model of innovation measurement for higher academic technical institutions in India. It is done through the novel technique in the field of enquiry called ‘Total Interpretive Structural Modeling (TISM)’. The framework indicates that technical innovation in Indian institutions takes place in four different stages. Patenting, which is widely accepted as the proxy of innovation, has emerged as the linkage indicator connecting innovation inputs (funds, staff, facility, training, policy and others) with outcomes (like spin-offs).

The second study empirically estimates the impact of public funds (by controlling for location, age and other factors) on academic research outputs like patents and publications. This study is based on the panel dataset of 54 comparable scientific departments of six Indian Institutes of Technology (IITs) for a period of five years (2009-2013) forming a balanced panel of total 270 data points. Standard Random Effect (RE) technique with cluster robust standard error estimators is used after testing various assumptions using F-test, Hausman Test and Breusch-Pagan Lagrange Multiplier (LM) test. The study reveals that support from the Indian government to academic institutions through Plan Fund (PF) takes the time period of four years to generate positive impact on patent and publication intensities. Support through Non Plan Fund (NPF) generates positive impact on patent intensity over the period of four years but its impact on publication intensity is immediate and significant. The immediate impact of PF on patent intensity is not positive which may be attributed to temporary infrastructural and bureaucratic delay in funds disbursement and procurement etc.

The third study examines the impact of institutional, disciplinary and individual factors on the scientific research output of IITs. It is found that among institutional factors: joint management of Intellectual Property (IP) activities by all stakeholders, and providing IP linked rewards has significant positive impact on the patent probability and intensity. However, making patenting important criteria for career advancement should always be complemented with supportive institutional infrastructure. Such policy should also be aligned

with the requirement and nature of disciplinary output and individual motivation to generate positive results.

The last study measures the relative technical efficiency of Indian academic institutions and disciplines based on their academic research output. It showed that several departments of IIT Bombay (Aerospace Engineering, Electrical Engineering and Physics) and IIT Madras (Biotechnology, Chemistry, Mechanical Engineering) outperform similar departments in other IITs in publication output. For patent output, none of the departments of the six IITs have consistently been able to utilize their input resources with full efficiency when they are compared with similar departments of different IITs.

This thesis contributes to the field of enquiry through novel conceptual framework that establishes a hierarchal association between multi-dimensional indicators of innovation in higher academic technical institutions. It also empirically tests those relationships from a developing country's context. Regarding the efficiency measurement, the thesis cautions issues in cross-field comparison of the research efficiency of different departments. The efficiency of various institutes should not be measured based upon the standard output criteria as different disciplines have different output requirements and orientation.

The empirical findings of the thesis shall assist policy makers who are in charge of Science, Technology and Innovation (STI) and education and research. Optimum allocation of public funds on operational and capital expenditure is necessary to strike a balance between short-term and long-term research activities of academic personnel in these institutes. Since government funding takes four years or more to generate substantial research output, taking policy decision regarding disbursement of funds based on only one or two years' research performance is not viable. The thesis supports increased operational funding of the institutes that is directly associated with increased publication and patent intensity. Regarding capital expenditure, i.e. expenses on large infrastructural projects like construction or renovation of buildings (academic, administrative, hostel or lab buildings etc.), funds should be allocated on projects that can enhance institute's research activity in the long term.

सार

वर्तमान थीसिस सार्वजनिक वित्त पोषित शैक्षणिक अनुसंधान संस्थानों द्वारा एक निम्न मध्यम आय वाले देश यानी भारत में नवाचार के चार अध्ययन करती है। पहला अध्ययन भारत में उच्च शैक्षणिक तकनीकी संस्थानों के लिए नवाचार माप के एक बहुआयामी वैचारिक मॉडल को विकसित करने पर केंद्रित है। यह in टोटल इंटरप्रिटेशनल स्ट्रक्चरल मॉडलिंग (TISM)' नामक पूछताछ के क्षेत्र में उपन्यास तकनीक के माध्यम से किया जाता है। रूपरेखा इंगित करती है कि भारतीय संस्थानों में तकनीकी नवाचार चार अलग-अलग चरणों में होता है। पेटेंटिंग, जिसे नवाचार के प्रॉक्सी के रूप में व्यापक रूप से स्वीकार किया जाता है, परिणाम के साथ नवाचार इनपुट (धन, स्टाफ, सुविधा, प्रशिक्षण, नीति और अन्य) को जोड़ने वाले लिंकेज संकेतक के रूप में उभरा है (जैसे स्पिन-ऑफ)।

दूसरा अध्ययन पेटेंट और प्रकाशन जैसे अकादमिक अनुसंधान के आउटपुट पर सार्वजनिक रूप से धन (लोकेशन, उम्र और अन्य कारकों को नियंत्रित करके) के प्रभाव का अनुमान लगाता है। यह अध्ययन छह भारतीय प्रौद्योगिकी संस्थानों के 54 तुलनीय वैज्ञानिक विभागों के पैनल डेटासेट पर आधारित है, जो पांच साल (2009-2013) की अवधि के लिए कुल 270 डेटा बिंदुओं का एक संतुलित पैनल बनाता है। क्लस्टर मजबूत मानक त्रुटि आकलनकर्ताओं के साथ मानक रैंडम प्रभाव (आरई) तकनीक का उपयोग एफ-टेस्ट, हौसमैन टेस्ट और ब्रेश-पैगन लैग्रेग मल्टीप्लायर (एलएम) परीक्षण का उपयोग करके विभिन्न मान्यताओं का परीक्षण करने के बाद किया जाता है। अध्ययन से पता चलता है कि योजना कोष (पीएफ) के माध्यम से भारत सरकार से शैक्षणिक संस्थानों को मिलने वाला समर्थन पेटेंट और प्रकाशन की तीव्रता पर सकारात्मक प्रभाव उत्पन्न करने के लिए चार साल की समयावधि लेता है। नॉन प्लान फंड (एनपीएफ) के माध्यम से समर्थन चार वर्षों की अवधि में पेटेंट तीव्रता पर सकारात्मक प्रभाव उत्पन्न करता है लेकिन प्रकाशन तीव्रता पर इसका प्रभाव तत्काल और महत्वपूर्ण है। पेटेंट तीव्रता पर पीएफ का तत्काल प्रभाव सकारात्मक नहीं है, जिसका श्रेय अस्थायी रूप से अवसंरचनात्मक और नौकरशाही में देरी के कारण हो सकता है।

तीसरा अध्ययन आईआईटी के वैज्ञानिक अनुसंधान उत्पादन पर संस्थागत, अनुशासनात्मक और व्यक्तिगत कारकों के प्रभाव की जांच करता है। यह पाया गया है कि संस्थागत कारकों में: सभी साझेदारों द्वारा बौद्धिक संपदा (आईपी) गतिविधियों का संयुक्त प्रबंधन, और आईपी से जुड़े पुरस्कार प्रदान करने से पेटेंट की संभावना और तीव्रता पर महत्वपूर्ण सकारात्मक प्रभाव पड़ता है। हालांकि, कैरियर की उन्नति के लिए महत्वपूर्ण मानदंडों को पेटेंट करना हमेशा सहायक संस्थागत बुनियादी ढांचे के साथ पूरक होना चाहिए। इस तरह की नीति को अनुशासनात्मक आउटपुट की आवश्यकता और प्रकृति और सकारात्मक परिणाम उत्पन्न करने के लिए व्यक्तिगत प्रेरणा के साथ गठबंधन किया जाना चाहिए।

अंतिम अध्ययन भारतीय अकादमिक संस्थानों और विषयों की सापेक्ष तकनीकी दक्षता को उनके अकादमिक अनुसंधान उत्पादन के आधार पर मापता है। यह दिखाया गया है कि IIT बॉम्बे (एयरोस्पेस इंजीनियरिंग, इलेक्ट्रिकल इंजीनियरिंग और भौतिकी) और IIT मद्रास (जैव प्रौद्योगिकी, रसायन विज्ञान, मैकेनिकल इंजीनियरिंग) के कई विभाग प्रकाशन उत्पादन में अन्य IIT में समान विभागों की तुलना करते हैं। पेटेंट आउटपुट के लिए, छह आईआईटी में से कोई भी विभाग लगातार अपने इनपुट संसाधनों का उपयोग पूरी दक्षता के साथ नहीं कर पाता है, जब उनकी तुलना विभिन्न आईआईटी के समान विभागों से की जाती है।

यह थीसिस उपन्यास वैचारिक ढांचे के माध्यम से जांच के क्षेत्र में योगदान करती है जो उच्च शैक्षणिक तकनीकी संस्थानों में नवाचार के बहुआयामी संकेतकों के बीच एक हाइरार्च एसोसिएशन की स्थापना करती है। यह विकासशील देशों के संदर्भ से उन संबंधों का अनुभवजन्य परीक्षण भी करता है। दक्षता माप के संबंध में, थीसिस विभिन्न विभागों की अनुसंधान दक्षता की क्रॉस-फील्ड तुलना में मुद्दों को ध्यान में रखती है। विभिन्न संस्थानों की दक्षता को मानक आउटपुट मानदंडों के आधार पर नहीं मापा जाना चाहिए क्योंकि विभिन्न विषयों में अलग-अलग आउटपुट आवश्यकताएं और अभिविन्यास होते हैं।

थीसिस के अनुभवजन्य निष्कर्ष नीति निर्माताओं की सहायता करेंगे जो विज्ञान, प्रौद्योगिकी और नवाचार (एसटीआई) और शिक्षा और अनुसंधान के प्रभारी हैं। परिचालन और पूंजीगत व्यय पर सार्वजनिक धन का इष्टतम आवंटन इन संस्थानों में शैक्षणिक कर्मियों के अल्पकालिक और दीर्घकालिक अनुसंधान गतिविधियों में संतुलन बनाने के लिए आवश्यक है। चूंकि सरकारी फंडिंग में पर्याप्त शोध आउटपुट उत्पन्न करने में चार

साल या उससे अधिक का समय लगता है, इसलिए केवल एक या दो साल के अनुसंधान प्रदर्शन के आधार पर धन के संवितरण के बारे में नीतिगत निर्णय लेना व्यवहार्य नहीं है। थीसिस उन संस्थानों के बढ़ते परिचालन वित्तपोषण का समर्थन करती है जो सीधे प्रकाशन और पेटेंट की तीव्रता के साथ जुड़े हुए हैं। पूंजीगत व्यय के बारे में, अर्थात इमारतों (शैक्षणिक, प्रशासनिक, छात्रावास या प्रयोगशाला भवनों आदि के निर्माण या नवीनीकरण) जैसी बड़ी अवसंरचनात्मक परियोजनाओं पर व्यय, उन परियोजनाओं पर धन आवंटित किया जाना चाहिए जो दीर्घकालिक में संस्थान की अनुसंधान गतिविधि को बढ़ा सकते हैं।

ACKNOWLEDGEMENT

I take this opportunity to express my humble and deep gratitude to the 'GURU' principle within all of us that helps us to understand, assimilate, nurture, disseminate and enhance the faculty of knowledge. This thesis work would not have been emanated, rest completed without the nurturing support of this principle.

I would like to express my humble and profound gratitude to Dr, Ruchi Sharma who introduced me to the area of "economics of innovation" and showed faith on me to take up this research work. Despite my limited capacity and understanding of the field she has constantly been a source of inspiration, encouragement and support. She undertook additional efforts to guide me and provide all research related counselling from thousand kilometers away. I will also cherish all the discussions held with her at different occasions and places during different phases of research. Even during much difficult and challenging phases of this research she motivated and counseled me like a friend. I am indebted to her for her kindness, support and guidance as a PhD supervisor.

I am fortunate to be associated with Dr. P. Vigneswara Ilavarasan whose work I had been following even before joining the PhD program. He generously provided his guidance and valuable suggestions from time to time in different phases of this work and has helped in every possible way to solve my queries and to deal with administrative challenges. I will always cherish the great experience that I had watching him teach and guide with enormous professionalism, dedication and expertise. All my hard work will be worthwhile if I am able to take even a single class of quality that he does.

This thesis has greatly improved with the suggestions and inputs of the Student Research Committee members (SRC) that comprises Dr. Harish Chaudhary (chairman), Dr. Seema Sharma (internal expert) at the Department of Management Studies (DMS), and Prof. V. Upadhyay (external expert) at the department of Humanities and Social Sciences (HSS). Suggestions provided by the SRC members have gone a long way in enriching the thesis to its present state of completion. I would also like to pay my humble gratitude to Prof S. K. Jain, Dr. Sanjay Dhir at DMS and Dr. Sourabh B. Paul at HSS who taught the course of Economics of Intellectual Property Rights (IPR), Innovation and technology transfer and Econometrics techniques, respectively. Lessons learned from their courses have not only helped in the present work but have also provided the building block for my research endeavors in future.

No words can express my gratitude towards the work of scholars and economists that has built the body of knowledge in the field of innovation and other related disciplines. Discussions conducted during conferences and on other occasions with Prof. Pierre Mohnen at UNU-MERIT, Prof. Xiaolan Fu at the Oxford University, Prof. Walter Park at the American University, Ms. Jyotsna Pandey at National Institute of Science Technology and Development has also benefitted this research immensely.

I am indebted to the fellowship of the Indian Institute of Technology Delhi (IITD) that provided the financial support to complete this thesis and to present the portions of its finding at various conferences. Each and every member of the office of the DMS, office of the post-graduate (PG) section, accounts section, office of the dean - student's affairs section are humbly acknowledged for their continuous and timely support throughout the research work.

The conceptual framework developed in the study is significantly benefitted by the inputs provided by experts like Prof. Sushil and Dr. Anil Wali at IITD; Dr. Shishir K. Jha and Prof. Kirankumar Momaya at Indian Institute of Technology Bombay (IITB); Dr. R. Mukundan at National Institute of Industrial Engineering (NITIE), Mumbai; Dr. Muqbil Burhan at FORE School of Management, Delhi; Mr. Yashwant Dev Parmar at Technology Information, Forecasting and Assessment Council (TIFAC), Delhi; Mr. Ashish Jha at Healthcare Innovation and Technology Lab, Gurgaon; Dr. Pankaj Parashar at Cutting Edge Medical Devices Pvt Ltd., Indore; and Dr. Abhay Bhadani at Yatra.com, Gurgaon.

The most challenging and time consuming part of the data collection was smoothened with the generous and timely support provided by Mr. V. K. Wadhwa, Dr. Kalyan Bhattacharya, and Dr. Neeraj Kumar Chaurasia at IITD. They have been consistently helpful in providing not only the critical sources and access to data but also for their expert suggestions during the work. The suggestions and support provided by Dr. Muqbil Burhan and Dr. Vinita Krishna for the data collection have also been valuable. The questionnaire based study is greatly benefitted from the expert suggestions from Dr. W. Selvamurthy at Amity Science, Technology and Innovation Foundation, Dr. Smita Sahu at AMITY university, Dr. Archana Chugh at the Kusuma School of Biological Science (IITD), and Prof M.R. Ravi Kumar at the Department of Mechanical Engineering – IITD. I am also thankful to all the academic researchers who have responded/not responded to the questionnaire for their time and patience.

Statistical analysis and econometric modelling has greatly benefitted from the stimulating discussions with my friends and fellow scholars at IIT Delhi (Rajeev Pandey, Dhanya Jothimani, Chitra Khari, Ashish Rathore and Vinita Krishna Mam) and immense support provided by friends at IIT Indore (Aparna Sharma, Madan Dhanora, Shadab Danish, Sidheswar Panda, Dr. Sanjay Kumar Lenka). I am also thankful to Anushruti Vagrani and Ashish Kumar Rathore at IITD who generously provided their timely and much needed support to manage teaching assistantship duties at IITD during my frequent visits to IIT Indore for research work.

My profound gratitude, love and respect for my parents, brother and sister-in-law who showed immense faith, patience, unconditional love and constant support throughout my journey of being a PhD scholar. Their heartfelt blessings and prayers have helped me in both seen and unseen ways to finish my thesis. My friends: Sonia Sharma, Garima Agrawal, Deepika Joshi, Rohit Kataria, Pooja Singh, Harshita Sharan, Darshna Banker, Syed Ziaul Mustafa, Ravi Shakar Giri all are greatly acknowledged for their much needed love, support, refreshments, treats and outings.

My friend and husband, Rajeev, who was a constant companion during initial years and life partner during later years of my PhD work has helped me emotionally and mentally throughout this period. He has acted as a catalyst to make me think about the research from different perspectives by raising most important but hidden questions about my work. He also motivated and encouraged me to extend my comfort zone and to learn new inter-disciplinary techniques which have greatly benefitted the present work. This thesis would not have come to the present shape without his constant inputs and support.

AKRITI JAIN

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

NKC	National Knowledge Commission
NIS	National Innovation System
S&T	Science and Technology
IPRs	Intellectual Property Rights
PBF	Performance Based Funding
GERD	Gross Expenditure on R&D
THE	Times Higher Education
TISM	Total Interpretive Structural Modelling
TRIPS	Trade-Related Aspects of Intellectual Property Rights
WTO	World Trade Organization
AUTM	Association of University Technology Managers
NBER	National Bureau of Economic Research
ECIS	European Community Innovation survey
OECD	Organization for Economic Co-operation and Development
SBA	Small Business Administration
NSF	National Science Foundation
ICT	Information and Communication Technology
PFRO	Public-Funded Research Organization
GMM	Generalized Method of Moments
AHP	Analytical Hierarchal Process
SAW	Simple Additive Weight
KPF	Knowledge Production Function
PwC	Price Waterhouse Cooper
FA	Factor Analysis

ARWU	Academic Ranking of World Universities
QS	Quacquarelli Symonds
OLS-FE	Ordinary Least Square Fixed Effect
NIH	National Institute of Health
UIC	University-Industry Collaboration
TTO	Technology Transfer Offices
MOOSRA	Multi-Objective Optimization based on Simple Ratio Analysis
SID	System of Innovation for Development
WDI	World Development Indicator
IPO	Indian Patent Office
UGC	University Grant Commission
SCI	Science Citation Index
CAGR	Compound Annual Growth Rate
WIPO	World Intellectual Property Organization
InPASS	Indian Patent Advance Search System
PF	Plan Fund
NPF	Non-Plan Funds
SSIM	Self-Structured Interaction Matrix
GUF	General University Fund
OLS	Ordinary Least Square
FE	Fixed Effect
RE	Random Effect