

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

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OF INDIAN ACADEMIA**

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*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.

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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 hierarchical 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 इंटरप्रेटेशनल 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, होसमैन 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, अर्थात् 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।

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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