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Characteristics of Indian Academic Research Underlying Industrial Innovations: An Empirical Analysis*

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There has neither been any systematic study on the characteristics of academic research that has contributed to product or process improvements in the industry, nor do we know how these projects are funded, and their size. This paper based on 71 Indian capital-goods firms offers insights on the sources, characteristics, and financing of academic research underlying innovations. The finding should be of interest to policy makers concerned with the directions of technical change and attempting to increase the economic value of academic research.

Introduction

Several trends have come together in recent years to make policymakers more interested in economic and other quantifiable measures of academic research success and benefits[1]. Technology is becoming an essential component of economic competitiveness. Government budget constraints are forcing policy makers to re-evaluate 'spending' and to look for ways to compare the value of widely divergent government programs. Academic research refers to studies carried out by academicians on their own (disseminated directly or indirectly) or sponsored (including consulting) research endeavors. In empirical studies, Jaffe[2] and Feldman[3] have shown that spillovers (positive, external technological efforts) from university research influence the spatial distribution of innovation output, measured as patent applications. There is even more reason to believe that spillovers exist from universities to firms, since the former have less incentive to try to keep research secret. Nelson[4], using surveys of research managers, found university research to be an important source of innovation in some industries, particularly those related to the biological sciences.

Research leads to productivity improvements and economic growth primarily through technological innovation. However the relationship between research and innovation can be long-term, indirect and unpredictable. Studies of technological innovations have shown them to depend on research results that are decades old and often of seemingly unrelated fields[5]. Moreover, the transformation of research into economically successful innovation depends on factors in the economy that are completely outside the research process. These factors include the climate for investment, government tax, regulatory and patent policy, the degree of competitiveness, and entrepreneurship in industry, the state of the capital market foreign competition, wages, unionization, and other characteristics of the work force. A highly successful basic research effort may never generate technological innovation, or pay-off economically, if other factors in the economy are not conducive to technological change. Applied research, which aims to find practical solutions to real-life problems, can be more closely associated with economic activity.

However, till date there are no studies examining the types of academic projects/programmes that had economic impact on industrial innovation. Information about the nature of funding, their budgets is also unavailable. The importance of this issue stems from observations that some of the emerging industries (biotechnology, software) and mature industries (metallurgy, machinery) have been deriving their technological competitiveness from useful interactions with institutes[6].

Analysis of academic research contribution shall be useful to understand the effectiveness of funding patterns of economically valuable projects. Knowing what percentage of technical changes were financed by gov-

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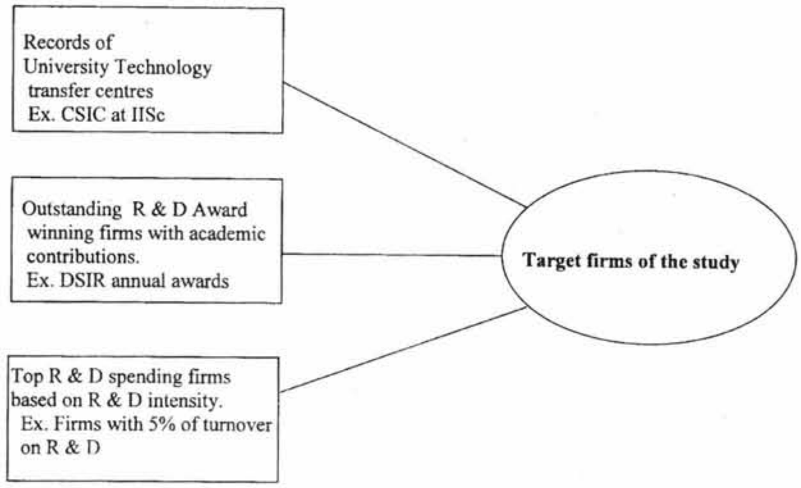

Figure 1 — The process of selecting the target firms for the study

ernment funds and private sources and what the sizes of these funding are, would indicate in what areas federal government can possibly channel its funds better. Information of this sort is useful to scholars and policy makers concerned with technology transfer and economic payoff from the nation's academic research. This is particularly important in view of the increasing investments being made in R & D both by the government and the industry. In this paper, we report the results of a study based on 71 manufacturing firms and 106 academic researchers. These findings subject to limitations, offer new insights on the sources, funding and control of academic research underlying industrial innovation.

Methodology

Sample

As the focus of the study is on assessing the characteristics of successful industrial innovations emanating from academic research, the unit of analysis for the study is a successful industrial innovation in a firm, arising from academic research. To identify the successfully transferred academic research contributions, initially, records of Centers of Technology Transfers located in most Institutes and Universities were contacted. The firms that have adopted these technologies were contacted. In addition, firms that have received awards for outstanding in-house R & D achievements with academic research contribution were also met. Recognizing the fact that technology-oriented firms are much more likely to be aware of and to use academic research, top 5 per cent R & D spenders from the above listed industries were contacted. Figure 1 presents the sample selection approach adopted for this study.

Firms in machinery and machine tools, electrical, chemical, metallurgy, drugs, accounting for just over 60 per cent of the manufacturing value added in India, were the target population. A design of 'deliberate sampling for heterogeneity', in which one defines the target population of firms, situations and times, to ensure that a wide range of firms within each class are represented, was followed[7]. Initially, 282 firms from the above sectors were contacted, briefed about the objectives of the study and asked to extend their support for providing relevant data. Of these, 124 firms sent letters of encouragement and only 71 provided complete information. The characteristics of sample firms in terms of size and sector are presented in Table 1.

Based on the pilot cases and Mansfield[8] a questionnaire was developed and pre-tested based on 19 firms in Bangalore and seven firms in Hyderabad with a view to assess the questionnaire in terms of: (a) Its 'understandability' by respondents, (b) Internal consistency, and (c) Suitability to the context.

Variables

To begin with, it is worthwhile to note that we needed data which could tell us what per cent of the industrial innovations could not have been developed (without substantial delay) in the absence of Indian academic research (occurring within some specific years of the innovations). While in some cases a direct estimate was possible (e.g., in cases such as Bangalore Genie Pvt Ltd, where the product ideas sprang from Indian Institute of Science, estimates of reduction in import of these materials were used), most often, objective measures were difficult. Additionally, if we were testing the

Table 1 — Industry and size details

Industry type	Size (in Rs million)			Total
	Large 10 million	Medium 5-10 million	Small Less than five million	
Drug	3	2	3	8
Metallurgy	3	3	4	10
Chemicals	6	3	2	11
Electrical	2	4	9	15
Mechanical	11	4	12	27

relationship between the size of University R&D budget, quality of faculty, and their commitment in development and the effectiveness of the innovation, need for perceptual data became important. Data about sales, R & D investment, number of new models introduced, number of patents, R & D personnel, and R & D awards during the years 1990-1997 were obtained. For the same years, details about collaborations with an academic institute, mechanisms used to obtain academic information, and preferred/experienced mode of academic knowledge transfer were also obtained.

To estimate the value of academic research, we obtained the percentage of product (process) developments that could not have been developed by the firm (without substantial delay) in the absence of academic work during 1990-1997. By Washington, D.C. Washington, D.C. substantial delay' we mean a delay of two years or more. We admit, this is arbitrary and lacks empirical verification. It is always hard to rule out completely the possibility, that in the absence of relevant academic research, industrial or government researchers might have provided the necessary information. But according to the firms, this would have been extremely unlikely for the innovations they included in this category. If we consider lag-effect of Indian market, in general, it could be assumed to be the year by which an incumbent/entrant would have introduced the product. We also measured the percentage of product (process) developments that were based on very substantial inputs from academic research during 1990-1997.

National indicators of academic institutes, in terms of publications and their impact, are available[9]. However, several other measures of university environment such as patents, cross-disciplinary orientation, small and medium industry support, information and feedback to industry were difficult to obtain. Hence, we adopted a perceptual measure on a five-point scale, on the lines of National Academy of Sciences[10] faculty ratings. For estimating the value of project related contribution; geographical proximity (measured as a category variable, 1 = within the state and 0 = otherwise), cost of the academic project and sources of financial support for the project (DST or CSIR) were measured. Perceptual measures of faculty commitment for transfer of technology, cost and time consciousness were also elicited.

We asked the executives to cite three prominent Indian academic researchers whose work had significantly contributed to development/improvement of processes and products. Wherever researchers had been hired to solve a new design or process we treated these interactions as significant contributors. We wrote to the cited researchers about the objectives of the study and sought their cooperation for identifying the sources of their research funding and types of projects undertaken. As some of the cited researchers were out of the country or had retired, we got the specific information from the heads of the departments or from the consulting division of the university. Finally, 106 researchers responded to the queries from 56 institutes spread throughout the country.

Results and Discusssion

In order to identify the industry-wise percentage of new products and processes we used the count from the questionnaire. As indicated in Table 2, about 5.12 per cent of the firms new process and about 3.88 per cent of their new products could not have been developed (without substantial delay) in the absence of academic research during 1990-97. The percentage of new products and processes, thus, on recent academic research seems to be highest in the chemicals industry and lowest in the mechanical industry.

Taken as a whole, the 71 firms cited 106 academic researchers from 56 institutes. Table 3 lists the universities and types of departments cited most frequently by the firms in each industry. In most industries, the most frequently-cited universities/ institutes are the premier institutes of Science and Technology (S&T). For example, Indian Institute of Science (IISc), Indian Institute of Technology (IIT) Madras, REC-Trichy, Indian Institute of Technology (IIT), Delhi are the most frequently cited in metallurgy, University Department of Chemical Technology (UDCT), University of Bombay was the most cited by Chemical and Drugs industry. IISc was the most cited in electrical engineering and IIT-

Table 2 — Percentage of new products and processes based on academic research

Industries	Percentage that could not have been developed (without substantial delay) in the absence of academic research		Percentage that were developed with very substantial aid from academic research	
	Process	Product	Process	Product
Drugs	6.0	2.87	7.85	6.25
Metallurgy	3.6	5.4	5.2	3.51
Chemicals	8.18	5.54	7.54	2.27
Electrical	3.86	3.6	8.0	3.61
Mechanical	3.96	2.03	5	4.4
Industry mean	5.12	3.88	6.71	4.0

** Industry mean refers to unweighted mean of industry figures

Table 3 — Universities and departments with the largest percentage of academic researchers cited by the sample firms as contributing to their process and product development

Drugs		Metallurgy		Chemicals	
University	Department	University	Department	University	Department
Bombay	UDCT	IISc	Metallurgy	Bombay	UDCT
(27 per cent)	(52 per cent)	(34 per cent)	(49 per cent)	(17 per cent)	(33 per cent)
IICT	Inorganic Div	IIT-Madras	Metallurgy	IITB	Chemical
(18 per cent)	(28 per cent)	(24 per cent)	(28 per cent)	(6 per cent)	(8 per cent)
IISc	Chemical Engg	REC, Trichy	Mechanical	IISc	Chemical
(12 per cent)	(11 per cent)	(17 per cent)	(10 per cent)	(4 per cent)	(5 per cent)
MKU	NeuroBiology	IIT-Kanpur	Solid state	BITS	Chemical
(6 per cent)	(9 per cent)	(7 per cent)	(4 per cent)	(4 per cent)	(3 per cent)

Electrical		Mechanical	
University	Department	University	Department
IISc	Electrical/HV	IITMadras	Mechanical/
(24 per cent)	(32 per cent)	(16 per cent)	(32 per cent)
IITD	Electrical	Madras	Mechanical
(9 per cent)	(16 per cent)	(12 per cent)	(21 per cent)

Madras was the most cited by mechanical industry. It is worth noting that mechanical engineering industry cited two graduate colleges for significant contributions. There are, however, many other universities and institutes whose contributions have been acknowledged by the sample firms.

With regards to type of department, it appears the bulk of cited academic research took place in departments closely associated to the technology of the industry. In the drugs industry, however the executives cited researchers from varied disciplines such as genetics, neuro-biological studies, biocehmical technology, visceral mechanisms, immunology, and pharmacology.

We ran a multi-dimensional scaling (MDS) to identify the characteristics of the university system that influence a firm's preference in dealing with them. The major advantage of MDS compared to factor analysis, is that the locations of the data dimensions are cartesian co-ordinates instead of angles as in factor analysis. Also, interpretations are more direct and useful[11]. Table 4 shows the results of the MDS which resulted in two dimensions. The first dimension relates to task and business focus of the university in industry interaction. Previous history of the institute is the highest loaded variable on the first dimension, thus indicating the augmentation effect in science. The second dimension concerns project overhead and activity management.

To identify the budget support of the cited project and sources we adopted the following strategy: Of the 106 cited researchers, only 69 were distinct citations. We corresponded with each of the distinctly cited researchers to obtain data about the research budgets and sources of support. In the case of the researcher being on a foreign visit or under retirement, data were obtained from the head of the institute or consulting division of the institute. Table 5 shows the per cent distribution of cited academic researchers by their average annual expenditure during 1990-1997. The research expenditure by the projects was high in only drugs and chemical industry. Engineering industries had all their projects in what could be termed as 'little science' projects.

We had asked the academic researcher details of sources of funding, and sequence of funding (whether government funding preceded private funding of the cited research or vice versa). Table 6 provides the sources of funding for cited academic researchers. Majority of the academic research funding came from Federal agencies such as Department of Science and Technology (DST), Ministry of Human Resource Development (MHRD), Defense Research Development Organization (DRDO) and Central Electricity Authority (CEA).

Table 4 — Results of MDS for university-academic researchers variables

Variables	Dimensions 1	2
Previous history	1.71	0.95
Task related	1.47	0.52
Business focus	1.34	0.34
IPR	1.00	0.35
General interest	1.00	0.17
Project related	0.22	1.15
Overhead	0.01	0.57

While government support was obviously important to the vast majority of the cited academic researchers, this does not mean that industry did not support many of them as well. Public sector giants like BHEL and BEML have funded some basic research projects. Even private sector firms such as Hero Honda, Tata and Sons, WS Insulators, and Grindwell Norton have made substantial contribution. Overall the industry supported a substantially smaller percentage of the cited academic research than did government (19.6 per cent vs 91 per cent). Only in the chemical industry did the industry's contribution compare with government support.

Table 7 shows the major sources of government funding for cited academic researchers. An overwhelming percentage of government funding of the academic research came from the Department of Science and Technology (DST) and the MHRD supported a significant portion of the academic research across industry disciplines. The results have to be interpreted with caution as several of the agencies had just come into existence (e.g., DBT) or started supporting funds only in the recent past (e.g., MHRD). Also, some of these agencies, by virtue of their focus, may not be funding projects from many industrial sectors. Hence, their contribution may appear to be weak. In the bulk of cited research, government funds supported initial experiments and concept testing and very often the industry funding furthered the work to definite products and processes.

Conclusions

A substantial portion of Drugs and Chemical Engineering industry processes and products have been developed based on academic research, though the invention itself may not have come from the researcher directly. Our results reveal, the small and medium industry focus intellectual property regime and industry interactions are perceived to be important for industry-institute interactions.

Table 5 — Percentage distribution of cited researcher by their average annual research expenditure expenditures, 1990-1997

Average annual expenditure of researcher	Industry citing the academic researcher: Drugs	Metallurgy	Chemical	Electrical	Mechanical
Less than 10 lakhs	25	17	23	4	13
10-50 lakhs	9	2	12	3	2
50-100 lakhs	11	0	3	0	0
> 100 lakhs	4	1	1	0	0

The expenditure includes institute overhead (average 10 per cent)

Table 6 — Sources of funding for cited academic researchers

Industry citing the academic researcher	Percentage of cited academic researchers whose research was funded (wholly or in part) during 1990-1997	
	Government funds	Industry funds
Drugs	75	24
Metallurgy	94	6
Chemicals	73	27
Electrical	95	5
Mechanical	89	11

Table 7 — Percentage of cited academic researchers with government funding whose research was financed (wholly or partly) by each agency

Government agency	Industry citing the academic researcher				
	Drugs	Metallurgy	Chemicals	Electrical	Mechanical
DST	61	78	65	65	53
MHRD	8	7	21	15	31
DRDO	2	11	1	7	10
MCF	3	0	4	0	0
MH	13	0	0	2	5
DBT	9	0	3	1	0
CSIR	4	4	6	0	0
DOT	0	0	0	8	0

With regards to government funding, the DST and the MHRD seem to play the predominant roles in financing academic research cited by the six industries studied here. DST is a major supporter of metallurgy and electrical industry related projects, the MHRD seems to be major supporter of mechanical engineering projects. The fact that DRDO seems to support academic researchers by a wide variety of industries, is noteworthy.

The findings regarding the funding of these projects reveal a complex web of financial and intellectual relationships among academic researchers, government agencies and firms. Most of the cited academic researchers pursuits have been supported by government funds. Private sector contribution was smaller- and followed federal funding. The private sector funding came more for concept testing and standardization.

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