University-Industry Interactions and Innovation in India: Patterns, Determinants, and Effects in Select Industries

K. J. Joseph * and Vinoj Abraham

Studies on innovation using innovation system perspective have assigned an important role for university industry interaction. However, most of these studies have been undertaken in the developed countries. In this context the present study, drawing data from a primary survey of firms covering different manufacturing industries and universities in four states of India, attempts at throwing light on a number of issues relating to the status of interaction, inducing factors and the innovative outcomes of interaction. Low levels of university industry interaction notwithstanding, the study suggests that firms that collaborated with universities achieved a higher level of innovative ability.

Keywords: University-industry interaction, Innovation, India

JEL Classification: O31, O33, D02

I. Introduction

The National System of Innovation perspective considers innovation as a non-linear, evolutionary and interactive process wherein institutions play a key role. Naturally studies on innovation in the NSI perspective have assigned a key role for universities and Public Research Institutions (PRIs) and there is a rich literature dealing with different aspects of relationship between universities, PRIs and the industry. While some examined the capacity of firms to interact and make effective use of knowledge flows from universities (Cohen and Levinthal 1989, 1990; Cockburn and Henderson 1998; Ziedonis 1999; Lim 2000), another set of studies analysed the characteristics of universities that generate knowledge flows of interest for industrial R&D and innovation (Henderson, Jaffe, and Trajtenberg 1998; Thursby and Thursby 2002; Feldman *et al.* 2002; Jensen and Thursby 1998; Jaffe 1989). A third set of studies analysed the different channels through which knowledge flow from universities to industry (Cohen *et al.* 1998; Cohen, Nelson, and Walsh 2002; Agrawal and Henderson 2002; Colyvas *et al.* 2002; Shane 2002). It is important to note that most of the studies were concerned with the experience in developed countries.

Of late there has also been growing interest on university industry interaction in developing countries (see Eun *et al.* 2006 for China). In case of India, the national policy towards science and technology has resulted in the establishment of a national network of research laboratories and large number of universities. The research laboratories had the mandate of undertaking research, with focus also on the region in which they are located, and the universities were primarily considered as centers of teaching. Presumably, by conceptualizing technological change as a combined outcome of technology import and domestic R&D, the national innovation system has been heavily oriented towards influencing either of these factors as per socio-economic considerations. While limited interaction between PRIs and the industry has been a point of concern, the focus of policy, until recently, has not been on promoting the interaction between the knowledge generating entities like universities and PRIs on the one hand and industries on the other.

In the recent years the dynamic role of university/PRI -industry interface in strengthening national technological capability and international competitiveness is increasingly being recognized. The New Economic

Policies launched in 1991 are, in a sense, driving universities towards industry and vice-versa. Consequently, the issues related to industry -academia interface are rapidly moving towards the forefront of science and technology policy making, planning and management. To elaborate, with the ongoing economic reforms there has been a drastic change in the economic environment confronted by firms, academia and public laboratories-protection is getting replaced with competition, controls are giving way to liberalization, import substitution is replaced with expert promotion and globalization. State support is increasingly being withdrawn from everywhere and in particular, the social sector activities including higher education and research. Therefore, the academic system will have to increasingly depend on the industrial sector (and the production sector of the economy more generally) for not only financing its research activities but even in its teaching activities. As for the industrial sector, with the opening up of the economy, firms are increasingly realizing that it is well-nigh impossible to compete even in the home market, let alone globally, using technology purchased from TNCs, when those very TNCs are the competitors in both markets. This in turn is forcing the industrial sector to look to academia for new sources of knowledge. Thus the ongoing policy environment appears to be instrumental in fostering a strong mutually reinforcing interaction between the academia and industry.[1]

These new developments notwithstanding, with possible exception of a few studies, university industry interaction in India remains an unexplored area. The existing studies have their limited relevance for broad based policy making as they are mostly case studies of leading S&T institute or laboratory (Chandra 2007 on IIT and Mashelkar 1996 on NCL) and of a specific industry (D'costa 2006 on software) or of select cities (Basant and Chandra 2007 on Bangalore and Pune). In this context, the present study, based on firm level data covering different manufacturing industries of four states in India has been an attempt at throwing light on a number of issues relating to industry university interaction.

The remainder of the study is presented as follows. Section two presents a brief description of the data base of the study and how it was collected. The third section opens with an examination of the

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[1] However, there is evidence to suggest that the process of globalization, left to itself, could be inimical to strengthening the industry academia interface (Brisolla 2000).

major sources of knowledge. The next section discusses the important channels of its transmission as perceived by the firms. Status of university-industry interaction and the inducing factors forms focus of discussion in section five and six. The seventh section explores the firm level characteristics of interaction while the innovative outcomes of such interaction is analyzed in section eight. Certain concluding observations are provided in the last section.

II. On Data Base of the Study

Perhaps the uniqueness of the present study, as compared to its predecessors on the issue at hand, is its reliance on a relatively large data set gathered though the primary survey. The sectors identified for the survey were Information Technology Sector, Chemicals including pharma and biotech firms, automobiles, textile and clothing industry, machine tools and others. India being a large country we had to be regionally selective. We have selected four industrially developed states, namely Maharashtra, Karnataka, Tamil Nadu, and Delhi. Within each state, excluding Delhi, the survey was conducted in two industrial cities. A purposive sampling technique was resorted to gather information from all the firms and researchers/professors who were willing to cooperate with the survey. In all the survey involved 460 firms and 735 professors/scientists. The universities covered in the survey are either purely technical universities or technical/science departments in general universities. There are a large number of engineering colleges and training institutes in the list. In addition a number of publicly funded research institutes were also included in the survey.

III. Firm's Sources of Knowledge

The innovation process involves interaction and knowledge sharing within and between firms and other knowledge generating entities. Most of the knowledge, however, not being codified innovation studies have characterized innovation as an interactive process. Hence the centrality of close interaction among actors has been considered important in the innovation process (Lundvall 1992; Lundvall and Johnson 1994). The universities are often seen as a source of new knowledge (Feldman 1994; Saxenian 1994; Anselin *et al.* 1997) and hence there exists the potential for knowledge spillovers. This has induced the scholars to
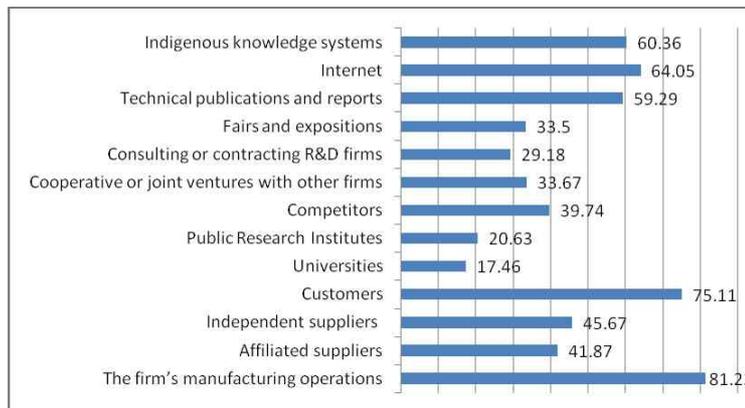
FIGURE 1

SUGGESTED SOURCES OF INFORMATION AND KNOWLEDGE FOR FIRMS

explore diverse ways in which knowledge flows from the university to firms like formal cooperation, through mobility of graduates, through informal social networks.

If the available empirical evidence is any indication, such interactions and knowledge sharing on a significant scale is yet to emerge in India's manufacturing sector. From the survey it was transpired that more than 81 percent of the firms considered their own manufacturing operations as an important source of knowledge for suggesting innovations (see Figure 1). The customers of the firm were the next important source of knowledge and information. Universities and public research institutes were reported to be less important source of knowledge. Only 17 percent mentioned universities as important sources of knowledge, while only 21 percent claimed PRIs to be important sources of knowledge. In terms of contribution of these sources also, the universities and PRIs and facilitating learning process, the firms in India's manufacturing sector adopts a strategy of looking inwardly rather than exploiting the sources of knowledge available with universities and public laboratories. This perhaps indicates basic character of an emergent innovation system characteristic of most developing countries.

In the literature, a distinction has been made in terms of the sources of information that contribute to innovative ideas and to the completion of innovation (Cohen *et al.* 2002). Using the Carnegie Mellon Survey on industrial R&D, Cohen *et al.* (2002) examined a broad range of information sources used by firms to innovate, of which one being

TABLE 1

SINGLE MOST IMPORTANT SOURCE OF
KNOWLEDGE AND INFORMATION FOR FIRMS

	suggested new project	contributed to new project
The firm's manufacturing operations	41.95	51.12
Customers	27.7	14.89
Technical publications and reports	3.69	6.18
Public Research Institutes	5.8	5.62
Consulting or contracting R&D firms	1.85	3.93
Independent suppliers (not linked through ownership)	4.22	2.53
Universities	3.17	2.53
Affiliated suppliers (parent, sister or subsidiary firm)	3.17	2.53
Internet	2.11	1.97
Cooperative or joint ventures with other firms	0.79	1.97
Competitors	2.64	1.69
Fairs and expositions	1.06	1.69
Indigenous knowledge systems	0.79	1.69
Others	1.06	1.68
Total	100	100

the R&D conducted in PRIs. It was found that with the exception of a few industries (pharmaceuticals, petroleum, *etc.*), PRIs do not play a central role in suggesting new ideas. In general, PRIs in developed countries are found out to be more important for innovation completion than for suggesting new ideas. Although the public research is less important than contributions from the vertical chain of production (suppliers, buyers, the firm itself), among the sources that are not in the production chain (competitors, consultants, joint ventures) PRIs are significant.

The evidence from the survey in India tend to suggest that neither universities nor PRIs have any important role as sources of information either in terms of suggesting new projects or help completing the existing ones (see Table 1). The respective share of universities and PRIs for suggesting new projects and completing the existing ones turned to be only about two to three percent. It is found that the firms' own manufacturing operations act as the major source of ideas for new projects and contributed to help completing the existing projects. The second most important source turned to be the customers.

IV. Channels of University-Industry Linkages

A number of studies (Cohen *et al.* 1998; Cohen, Nelson and Walsh 2002; Agrawal and Henderson 2002; Colyvas *et al.* 2002; Shane 2002) attempted at analyzing the channels through which knowledge flow from PRIs and University to industry. These channels include, but not limited to, personal networks of academic and industrial researchers (Liebeskind *et al.* 1996; MacPherson 1998), spin-offs of new firms from universities (Stuart and Shane 2002), participation in conferences and presentations, and flows of fresh graduates to industry (Varga 2000). Cohen, Nelson, and Walsh (2002) find that the channels of open science, especially publications, public meetings and conferences and also informal information exchange and consulting, are the most important in the U.S. Cooperative ventures do not seem to have been so important as other channels for industrial R&D. These results are controversial in relation to European contributions. For instance, based on a survey of firms and universities, Meyer-Krahmer and Schmoch (1998) find that collaborative research and informal contacts are the most important channels of communication. In a sample covering seven EU countries Fontana *et al.* (2004) found that PRIs are not seen by firms as playing an important role in the innovation process, about half of the firms have nonetheless developed formal collaborations with PRIs.

In our survey we have listed the important channels of information about the R&D activities or innovations of other firms and requested firms to indicate the importance of each of channels in term of their contribution to innovative activities. The firms use multiple sources of information generated by the universities/PRIs. We employ factor analysis as a data reduction tool to explore the most important set of factors affecting industry-academia interaction. The extraction method used is the principal component analysis and the rotation method used in Varimax using Kaiser normalization. Based on a threshold of eigenvalue of more than one, two factors were extracted. Factor loading 1 explained more than 57.7 percent of the total variance while factor loading 2 explained 8.8 percent of the variance. Keeping the threshold for factor loading as 0.7 as suggested by Carmines and Zeller (1982), seven of the fifteen sources of linkages were found to be important from the factor loading 1. These important linkages were contract research with universities, joint or cooperative R&D projects, partici-

TABLE 2

FACTOR ANALYSIS OF CHANNELS OF UNIVERSITY-INDUSTRY LINKAGES

Channels	Factor Loading	
	Factor 1	Factor 2
Patents	0.296	0.692
Publications and reports	0.130	**0.849**
Public conferences and meetings	0.328	**0.764**
Informal information exchange	0.319	**0.760**
Recently hired graduates with advanced degree	0.517	0.590
Licensed technology	0.470	0.601
Consulting with individual researchers	0.674	0.489
Contract research with universities	**0.737**	0.399
Joint or cooperative R&D projects	**0.741**	0.371
Participation in networks that involve universities	**0.767**	0.347
Temporary personnel exchanges	**0.702**	0.386
Incubators	0.689	0.266
Science and/or technology parks	**0.721**	0.306
Firm is owned by an university (URE)	**0.851**	0.206
Firm is a spin-off of an university	**0.848**	0.175
Eigen value	8.656	1.326

Notes: 1) Extraction Method: Principal Component Analysis.
         2) Rotation Method: Varimax with Kaiser Normalization.

pation in networks that involve universities, temporary personnel exchanges, science and/or technology parks, firm is owned by an university (URE), firm is a spin-off of an university (see Table 2).

These factors are all mostly established through formally structured methods of interaction rather than informal structures. Under the 2nd factor loading the important sources of linkages were publications and reports, public conferences and meetings and informal information exchange. These are mostly openly available sources of information. Thus the major sources of information for industries from universities appear to formalized channels and open channels, while informal channels are not important.

In the case of PRIs Factor loading 1 explained more than 58.5 percent of the total variance while factor loading 2 explained 9.3 percent of the variance. The important linkages were from the first factor were Contract research with universities, Joint or cooperative R&D projects, Participation in networks that involve universities, Science and/or technology parks, Firm is owned by an university (URE), Firm is a spin-off of an university (see Table 3), The 2nd factor loading had

TABLE 3
ANALYSIS OF CHANNELS OF PRI-INDUSTRY LINKAGES

Channels	Factor Loading	
	Factor 1	Factor 2
Patents	0.248	**0.750**
Publications and reports	0.167	**0.795**
Public conferences and meetings	0.302	**0.770**
Informal information exchange	0.273	**0.798**
Recently hired graduates with advanced degree	0.402	0.640
Licensed technology	0.384	0.588
Consulting with individual researchers	0.631	0.554
Contract research with universities	0.685	0.533
Joint or cooperative R&D projects	**0.705**	0.451
Participation in networks that involve universities	**0.733**	0.439
Temporary personnel exchanges	0.690	0.424
Incubators	0.664	0.381
Science and/or technology parks	**0.730**	0.341
Firm is owned by an university (URE)	**0.902**	0.146
Firm is a spin-off of an university	**0.896**	0.145
Eigen value	8.78	1.40

Notes: 1) Extraction Method: Principal Component Analysis.
2) Rotation Method: Varimax with Kaiser Normalization.

the following linkages as important sources: Patents, Publications and reports, Public conferences and meetings, Informal information exchange. The major sources of information for industries from PRIs also seem to occur through formalized channels and open channels, similar to universities.

V. Status of University-Industry Interaction and Inducing Factors

A. *Extent of Interaction as Perceived by Firms*

Various studies, especially from the developed world pointed towards the important role of interaction of firms with universities and public research laboratories. Such interaction has a longer history in developed countries like U.S. as evident from Rosenberg and Nelson (1994). During the last two decades, the competitive nature of the university environment in the U.S., along with legislation such as the Bayh-Dole Act, which gave universities title to innovations that took place inside their

walls, have caused universities to adopt policies to encourage, or at least to permit, the continuing involvement of academic researchers, thus facilitating the transfer of ideas to the private sector. This has induced a large number of studies analysing the nature extent and outcome of university industry interactions. Hall *et al.* (2003) report that about 60 percent of the research projects funded by the Advanced Technology Program in the U.S. involved firms in collaboration with universities. Zucker *et al.* (1998) studied the formation of firms in biotechnology, which is an industry closely linked to fundamental molecular biology. Their analysis shows that top U.S.: university researchers contribute to set up biotechnology firms. Mansfield (1998) finds that industrial innovations that could not have been developed (without a delay of a year or more) in the absence of academic research accounted for over 5 percent of total sales in major firms in the U.S. in 1994.

Evidence from other developed countries is not much different. Through a postal questionnaire survey of 2,300 companies, Beise and Stahl (1999) replicated Mansfield's survey in Germany and fund that approximately 5 percent of new product sales could not have been developed without academic research — a finding very similar to that of Mansfield. Caloghirou *et al.* (2001) analyzed over 6,000 Research Joint Ventures (RJVs) in 42 nations that received funding from the European Commission during 1983-1996 and found that the share of RJVs that involved one or more universities was 67 percent in 1996. Another study on the formation of firms in the regions of West Germany (Harhoff 1999) reported that the nearness to scientific personnel was important mainly for technology intensive entry. Thus the increasing evidence available from other developed countries of Europe tends to suggest that university-industry linkage in the American economy often correspond to findings from European and other countries.

In case of India's manufacturing sector, we find that the incidence of interaction with universities as reflected by the respondents to the survey is very low. Of the 462 firms that undertook the survey only 11.27 percent claimed that they had any form of collaboration with a university or a PRI (Table 4). However, there are considerable regional variations on this regard. Even when the total figures were very low, the interaction levels were high in Mumbai, with more than 31 percent of the firms collaborating with research institutes or universities (Table 5). Here it needs to be noted that Mumbai is the traditional industrial

TABLE 4

INCIDENCE OF FIRM INTERACTION WITH UNIVERSITIES/PRIS

	Freq.	Percent	Cum.
YES	52	11.33	11.33
NO	407	88.67	100
Total	459	100	

TABLE 5

SHARE OF FIRMS THAT COLLABORATED WITH A UNIVERSITY OR RESEARCH LAB

Center	Collaborated	Not collaborated	Total
Mumbai	31.46	68.54	100.00
Chennai	10.53	89.47	100.00
Bangalore	13.56	86.44	100.00
Pune	3.77	96.23	100.00
Coimbatore	1.11	98.89	100.00
Delhi	6.78	93.22	100.00
Total	11.26	88.74	100.00

capital of the country and that industrial development here has a longer history than other cities discussed here. Here it appears that similar to innovation the university-industry interaction is also an evolutionary process and it takes time for the institutional arrangements to emerge that facilitate the interaction.

B. Extent of Interaction as Perceived by Professors/Scientists

Having examined the feedback from the survey of firms with respect to university Industry interaction let us now briefly examine the feedback from professors. To begin with we have explored the perception of respondents with respect to the relative importance that they assign to different functions that universities discharge. As expected about 85 percent of the respondents were of the view that teaching and research are either very important or extremely important (Table 6). What is relevant for our discussion is to note that about 74 percent of the respondents were of the view that entrepreneurial and industrial-research lab cooperation also either very important or extremely important indicating the growing importance of university industry inter-

TABLE 6

PROFESSORS' PERCEPTION OF IMPORTANCE OF
THE DIFFERENT FUNCTIONS OF THE UNIVERSITIES

	Relative Importance					
	Not at all important	Fairly unimportant	Im-portant	Very Important	Extremely Important	Total
Teaching	0.68	0.82	12.65	33.74	52.11	100
Research	0.54	2.18	14.99	37.19	45.1	100
Entrepreneurial and industrial-Research lab cooperation	1.23	5.46	29.06	37.65	26.6	100
Social/community service	0.96	5.75	30.1	39.4	23.8	100

TABLE 7

DEGREE OF INDUSTRY-UNIVERSITY COOPERATION FOR
DIFFERENT TIME PERIODS

Period	Very weak	Somewhat weak	Average	Somewhat strong	Very strong	Total
Prior to 1991*	21.35	14.58	33.59	20.05	10.42	100
Between 1991 and 2000*	9.01	12.01	38.8	29.56	10.62	100
After the year 2000	6.23	5.9	29.84	37.54	20.49	100

Note: * Only if you were employed (appointed).

action. Also it must be noted that to a question if they encourage university industry interaction 96 percent of the professors replied in affirmative.

As the academia in general welcome grater interaction with industrial sector, there are also evidence to suggest that the degree of university industry interaction has been increasing over the years. From Table 7 it is evident that only 30 percent of the professors were of the view that the degree of interaction has been some what strong or very strong prior to 1990. However over 57 percent felt that the degree of interaction became somewhat strong or very stronger since 2000. Similarly over 21 percent felt that the degree of interaction was weak prior to 1991 where as only 6 percent felt that the interaction is very weak since 2000. On the whole there are ample evidence indicating that the university industry collaboration has been increasingly valued

TABLE 8

IMPORTANT FORMS OF INDUSTRY-UNIVERSITY COOPERATION

	Percent of total respondents (total respondents = 735)		
	Currently most active forms of industry-university cooperation in your institute (A)	Forms of cooperation that need to be emphasized in the future (B)	Forms of cooperation you have been involved personally (C)
Non-periodic consultation, on-site supervision, lecture, and other activities for industry	23.5	16.7	36.3
Participation and discussion in industry-related conferences and seminars	40.0	32.9	40.3
Consultation, supervision, and other activities for companies as official consultants	31.3	27.2	41.8
On-campus training for industry's personnel	19.9	19.2	30.5
Cooperative research with company researchers leading to publication of articles or registration of intellectual property, all without a formal contract with the company	16.7	27.1	19.5
Sharing of research facilities and equipments between laboratory and industries	21.8	28.6	33.7
Collaborative or trusted research under formal contracts with industries	14.1	22.3	29.3
Student internships to industries	14.1	13.6	35.9
Your own participation in industries as the director or staff	6.9	8.6	21.2
Creating your own start-up company	1.1	11.2	8.3
Others	0.1	0.3	0.3

by the academia and the degree of interaction has been increasing over the years.

As already indicated, the interaction between the university and industry could take different forms. In what follows we shall explore the most important forms of interaction as indicated by the involvement of the respondents (see Table 8). Here it may be noted that there

is some difference between the most active forms of industry- university cooperation as prevalent today and the form of interaction that the respondents are currently involved in. For example student internships to industries is one of the important (35.9) form of interaction in terms of the respondents' involvement where is only 14 percent felt that it is currently an important form of interaction. The most important form of interaction as now are consultation, supervision, and other activities for companies as official consultants Participation and discussion in industry-related conferences and seminars, non-periodic consultation, on-site supervision, lecture, and other activities for industry. Interestingly, cooperative research with company researchers leading to publication of articles or registration of intellectual property is yet to emerge as an important form of collaboration.

VI. Inducing Factors for University-Industry Interaction

Though the extent of interaction with the universities is generally found lower, the survey explored the reasons that induced the firms to interact with the universities. It may be noted that in all the 10 reasons specified in Table 9 the score is more than 3 and that it indicates that all these factors were considered important by the firms. Yet it is important to note that the most important reason for approaching the universities or PRIs is to help quality control and make use of the testing equipments available with the universities and PRIs. All the first three factors in fact point towards the firms desire to make use of the facilities. Equally import for the firms is to make an earlier contact to get excellent university students. In general, as far as those interacting firms are concerned, there are a number of reasons that induce them to interact with the universities.

The survey also enabled us to ascertain why the large number of firms were not inclined to interact with the Universities and or PRIs. The responses to a query on the reasons for not using universities /PRIs as sources of innovation information are recorded in Table 10. More than 37.8 percent of the respondents reported that their firm's R&D is enough to innovate. This meant that a large number of firms agreed that the firm's internal sources or firm specific sources of information were sufficient for innovation.

Universities/PRIs not having understanding of their line of business was another important reason. Literature identifies these factors as

TABLE 9

FACTORS INDUCING FIRMS TO INTERACT WITH THE
UNIVERSITIES/PUBLIC RESEARCH INSTITUTES

	Likert Scale
To help in quality control	4.14
To perform tests necessary for your products/processes	3.96
To use resources available at universities and public labs	3.82
To contract research helpful to the firm's innovative activities (complementary research by universities and public labs)	3.68
To get information about engineers or scientists and/or trends in R&D in the field	3.65
To make earlier contact with excellent university students for future recruiting	3.65
To augment the firm's limited ability to find and absorb technological information	3.51
To get technological/consulting advice from researchers and/or professors in solving production-related problems	3.48
Technology transfer from the university	3.40
To contract research that the firm cannot perform (substitutive research by universities and public labs)	3.25

TABLE 10

REASONS FOR NOT INTERACTING WITH UNIVERSITIES AND PRIs

	Most Relevant (%)	Context
Our firm's R&D is enough to innovate	37.8	Firm specific
Universities have no understanding of our line of business	23.78	Cultural
Public research institutes have no understanding of our line of business	19.82	Cultural
Contractual agreements are difficult	17.99	Transaction costs
Lack of trust	18.9	Transaction costs
Quality of research is low	14.68	Other
University concerned only with *big science*	17.13	Cultural
Geographic distance	10.06	Other
Difficulties in dialogue	10.67	Cultural
Intellectual properties issues	20.43	Transaction cost

TABLE 11

EXTENT OF SUCCESS IN TERMS OF MEETING THE EXPECTED OBJECTIVES

Responses	Freq	Percent
Yes, so far collaboration has been successful to meet the objectives	32	62.75
No, collaboration has not been successful to meet the objectives	5	9.8
Collaboration is still going on but I trust the objective will be met in due time	12	23.53
Collaboration has not been completed yet but I do not expect the objective to be met	2	3.92
Total	51	100

'*Cultural factors*,' wherein the inherent difference in the universities/ PRIs research and that of the requirement of firms make them irrelevant for the firms. Nearly 24 percent of the firms reported that universities do not understand their line of business, while nearly 20 percent of the firms stated that PRIs did not understand heir line of business. This is again reflected in the firms' affirming that universities were involved in big science, and not in tune with the requirement of the firms. 17 percent of the firms affirmed this as very relevant.

The third most important factor was linked to high levels of *transaction costs*. Nearly 18 percent of the firms stated that contractual agreements were difficult with universities/PRIs and nearly 19 percent said that there was lack of trust between the universities/PRIs and firms as contractual agreement. Intellectual property rights issue between the firm and public institutions, another source of transaction costs, was recorded as another important reason for firms not interacting with universities/PRIs. However, contrary to expectations, geographic distance and difficulties in dialogue does not seem to have a great role in making the universities/PRIs relevant to firms.

Though the present level of interaction is low and that there are a number of reasons for not having higher level of interaction, an over all assessment of those interacting forms have an encouraging response. To a query as to extent to which the interaction has been successful in achieving the declared objectives, a large majority (about 63 percent) respond- ed that the collaboration has been successful in meeting the objective for which collaboration was initiated (Table 11). More import-

TABLE 12

IMPORTANCE OF RESEARCH OUTPUTS OF UNIVERSITIES/PRIs FOR
INNOVATIVE ACTIVITIES OF FIRMS

	Not important	Slightly important	DK/ CS	Moderately Important	Very important	Total	Likert Scale
Research findings	15.69	26.58	1.53	24.4	31.81	100	2.7694
Prototypes	26.36	24.18	2.18	31.15	16.12	100	2.4355
New techniques & instruments	23.31	18.08	1.53	21.79	35.29	100	2.7365
Laboratories/ Metrology	25.66	21.93	2.19	25.66	24.56	100	2.5569

Note: DK/CS: Do not know or cannot say.

ant, only less than 10 percent responded that the collaboration was a failure.

In addition it was also discerned from the survey that all the important research output of universities like research findings, prototypes, new techniques are reported to be either moderately important or very important by more than 50 percent of the firms that reported any interaction with the universities. In terms of the likert scale, the research findings are most important followed by new techniques (Table 12).

VII. Firm-Level Characteristics of University-Industry Interaction

Now we shall proceed to identify the characteristics of the firms that use the various channels of information of the universities and PRIs. We also analyze the firm characteristics of university/PRI interaction.

There are several sources of information generated by the university/ PRI that the firms use such as Patents; Publications and reports; Public conferences and meetings; Informal information exchange; Recently hired graduates; Licensed technology; Consulting with individual researchers; Contract research with universities; Joint or cooperative R&D projects; Participation in networks that involve universities; Temporary personnel exchanges; Incubators; Science and/or technology parks; University owned Firms; Firm as a spin-off of university. The ordinal

ranking of these sources of information collected through the survey for both universities and PRIs are summed up to quantify the degree of use of these various sources of information by the firms. Mann-Whitney *U tests* are then employed to identify the firm characteristics in the utilization of these sources of information.

Studies have already highlighted certain firm characteristics that influence the interaction with universities and PRIs. In a regression analysis, Cohen *et al.* (2002) take size and age of the firm as the two explanatory variables. Larger firms and start-ups have a higher probability of benefiting from academic research implying a non linear relationship between size and interaction. Other studies (Arundel and Geuna 2004; Schartinger *et al.* 2001) incorporated explanatory variables, such as level of R&D expenditure, degree of firms' innovativeness. Yet another study (Laursen and Salter 2003) introduced the concept of 'open' search strategies of firms into this literature. Firms that adopt open search strategies have a higher probability of considering the knowledge produced by universities as important for their innovation activities.

Mohnen and Hoareau (2002) find that firms that cooperate with universities are generally large, are active in scientific sectors, patent and receive government support. Firms that are part of a group and cooperate, rely less on collaborations with universities than with independent firms. Mohnen and Hoareau hypothesised that in a conglomerate, collaborations with universities are established at the headquarters level. Another paper by Mansfield and Lee (1996) finds that firms prefer to work with local university researchers, usually within 100 miles from the firm's R&D laboratories, though differences are identified between basic research and applied research. Karlsson and Andersson (2005) analysed the locational relationship between industry R&D and university R&D in Sweden using a simultaneous equation approach and found that the location of industrial R&D is quite sensitive to the location of university R&D, and that the location of university R&D is sensitive to the location of industrial R&D.

Following the evidence from literature we have considered the firms characteristics like organization of R&D, size, age, and location of the firm as factors influencing interaction (Table 13). For the purpose of analysing the effect of these variables on the firms preferences of the various channels of information we sum up the ordinal ranking given by each firm for their preference of different channels of information. Then we compare the conditional mean rank of the two groups (de-

TABLE 13

SOURCES OF INFORMATION FROM UNIVERSITY/PRIS AND
FIRM CHARACTERISTICS

Types of firms by	Source of Information from University		Source of Information from PRIs	
	Mean rank	Asymp. Sig	Mean rank	Asymp. Sig
Organization of R&D				
Regularity of R&D				
Non-Regular R&D	243.2739		247.3799	
Regular R&D	190.7409	0.0001	180.4105	0.000
Centralisation of R&D				
Non-Centralized R&D	217.6966		210.0172	
Centralized R&D	230.9249	0.2791	237.1408	0.026
Intensity of R&D				
RD intensity <5% of sales	214.2623		209.88	
RD intensity >=5% of sales	233.6942	0.1115	235.82	0.033
Age, Size, and Region				
Age of the firms				
Younger (less than 15 years)	177.0302		169.09	
Older	205.3094	0.0121	211.26	0.000
Size of the firm				
Small (less than 50 employees)	219.7787		215.81	
Large Firms	269.4342	0.0233	300.03	0.000
Region				
Not in megacity	163.2474		159.89	
Mega city	271.442	0.000	272.68	0.000

pending on the factor to be analysed) using the *Mann-Whitney U test*. The mean ranking and the asymptotic significance levels are reported in Table 13.

IT is interesting to note that firms with non-regular R&D use the sources of information from the university and PRIs more than those firms with regular R&D. Firms with centralized R&D were not different in using the sources of university information from that of non-centralized R&D. But such firms used the information from PRI significantly from those non-centralized firms. Firms with higher R&D intensity (R&D investment as share of sales) were also found to use higher level of information sourced from PRIs in comparison to firms with lower R&D intensity (Table 13). However, firms that use these information sources from the universities did not seem different in the centralization of R&D, and intensity of R&D, unlike PRIs. Thus, in

TABLE 14
UNIVERSITY/PRIs INDUSTRY COLLABORATION AND FIRM CHARACTERISTICS

Types of firms by	Mean rank	Asymp. Sig
Organization of R&D		
Regularity of R&D		
Non-Regular R&D	27.03	
Regular R&D	23.35	0.397
Centralisation of R&D		
Non-Centralized R&D	22.74	
Centralized R&D	29.23	0.153
Intensity of R&D		
RD intensity <5% of sales	23.85	
RD intensity >=5% of sales	24.74	0.843
Age, Size, and Region		
Age of the firms		
Younger (less than 15 years)	15.43	
Older	18.31	0.401
Size of the firm		
Small (less than 50 employees)	24.98	
Large Firms	21.71	0.587
Region		
Not in megacity	24.58	
Mega city	24.49	0.988

India the link between organization of R&D seem to be stronger with PRI sources of information in comparison to universities.

Yet, the firm level characteristics such as age of the firm, size of the firms and location of the firms were found to be differentiating characteristics for the use of sources of information both from the universities and PRIs. Older firms (above 15 years of age) utilized the various sources of information more, both from universities and PRIs, in comparison to younger firms. Similarly larger firms (with more than 50 employees) utilize the sources of information from both universities and PRIs more than the smaller firms. Also, firms that were located in mega cities (with population of more than 5 million) used these sources of information from universities and PRIs more than firms that were located in smaller cities.

The analysis was extended to understand the characteristics of firms that collaborated with universities/PRIs (Table 14). The degree of industry-academia collaboration was measured as the sum of the responses to the ordinal ranking of 'reasons for collaboration' in the survey. The reasons given for collaboration were Technology transfer;

technological/consulting advice from researchers; To augment the firm's limited ability to find and absorb technological information; To get information about engineers or scientists and/or trends in R&D in the field; To contract research helpful to the firm's innovative activities; To contract research that the firm cannot perform; To make earlier contact with excellent university students for future recruiting; To use resources available at universities and public labs; To perform tests necessary for your products/processes; and To help in quality control.

However the results show that there was not any significant difference in firm characteristics in the degree of collaboration with universities/PRIs. The degree of collaboration of firms with regularity of R&D, centralized R&D and higher R&D intensity were not different from that of those firms with lower levels of regularity, centrality and intensity of R&D. Similarly, age, size, and location of firms did not discriminate the firms in terms of their degree of industry-academic collaboration. The insignificance of the result may be due to the thinness of the sub-sample of firms that reported interaction with universities. Of the 462 firms surveyed only 52 reported having industry-academy interactions.

VIII. Innovative Outcomes of University-Industry Interaction

Starting with Nelson (1986) a large number of formal studies have presented evidences of a positive impact of university R&D on firm performance. The survey supports the view that there is substantial innovative activity occurring within the surveyed firms. Of the 462 firms that were surveyed nearly 96 percent of the firms claimed that they had introduced a new product or a new process, or both during the three year period preceding the survey, which was carried out in early 2008 (see Table 15). Of the surveyed firms the single largest innovative activity was in introducing new products. More than 58 percent of the firms reported introducing new products, while only 17 percent of the firms introduced a new process, and 19 percent of the firms introduced both product and process innovations.

The innovative activity across various industries differs considerably. While there is not much difference in the proportion of firms being innovative, ranging between 89 and 98.5 percent, there is a large variation in type of innovation (Table 16). In the textile and garments industry the innovative activity is mostly focused on product innovation (91 percent of the firms did product innovation) while in IT and

TABLE 15
NEW PRODUCT/PROCESS INTRODUCED IN THE LAST 3 YEARS

	Freq.	Percent
No new product/process	28	6.06
New product	268	58.01
New Process	77	16.67
New product and process	89	19.26
Total	462	100

TABLE 16
NEW PRODUCT/PROCESS INTRODUCED IN THE LAST 3 YEARS BY INDUSTRY

Industry	No new product/ process	New product	New Process	New product and process	Total
Pharma, Chemical & Biotech	4.8	52.4	11.1	31.8	100
IT and Electronics	4.4	40.0	36.7	18.9	100
Automobile	4.8	59.5	7.1	28.6	100
Textile and Garments	2.2	91.1	2.2	4.4	100
Machine tools	1.5	73.1	13.4	11.9	100
Others	10.97	54.19	15.48	19.35	100

Electronics the innovative activity was relatively more focused on new processes (37 percent). In the automobile and Pharma industry relatively both product and process innovation is taking place.

However the weak nature of innovative activity of the firms gets revealed when one compares the novelty of the product. Of the 305 firms that claimed product innovation only 12 firms could claim that the product was new to the world, that is a radical product innovation, while 42 firms claimed that their product was new to the country though not new to the world, while 114 firms stated that their innovation was local in nature (Table 17). Thus product innovation seems to be heavily focused on bringing in novelty at the local level. Moreover, such innovation was, for the majority of the firms, mostly a random one time activity, rather than a continuous procedure. One could see that nearly 70 percent of all innovative activity within the firms occurred to a maximum of two products in the reference period of three years.

There are also considerable inter-industry variations in the innovative activity of firms as well. In the case of Pharma and Chemical industry

TABLE 17

FREQUENCY OF IMPROVEMENT OF EXISTING PRODUCTS BY FIRMS

Frequency of improve- ment	Improvement in product		New for the Firm but not for country		New for the Country but not for the world		New to the world	
	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent
1	131	42.95	58	50.88	15	35.71	7	58.33
2	71	23.28	22	19.3	14	33.33	3	25
3	38	12.46	13	11.4	2	4.76		
4	18	5.9	4	3.51	1	2.38		
5	13	4.26	5	4.39	5	11.9		
>5	34		12	8.9	5	11.9	2	16.66
Total	305	100	114	100	42	100	12	100

product improvement occurred more than three times in 45 percent of the firms that claimed to have done any product innovation. This was also case for IT and Electronics industry (35 percent) and Machine tools industry (34 percent). While in Automobile and the garment and textile industry such activity was limited to less than three times during the three year period. Even the intensity of such activity in terms of novelty for the country and the world also Pharma and chemical industry is doing better compared to other industries. The intensity of innovative activity was the weakest in the Automobile industry and textile industry compared to other industries.

Compared to product innovation, process innovation was weaker. Of the surveyed firms there were only 139 instances of process innovation (Table 18), while as shown above there were 305 instances of product innovation. There were just 41 instances of processes that were new for firm, 21 new for the country and 7 new to the world. Also such innovation in process occurred at very less frequency. Such improvement in process occurred typically once or twice in the three year period. Process innovation within the textile and garment industry has been nil, process innovation had been comparatively low in the pharma and chemical industry while it had been comparatively at a higher level in the IT and electronics industry.

Given the focus of the present study it is imperative to look into the effect of industry academia interaction on the innovative activity of the firms. Literature supports the view that higher levels of I-A interaction could lead to increased ability for innovation by firms. The survey

TABLE 18

NUMBER OF TIMES OF IMPROVEMENT OF AN EXISTING PROCESS BY A FIRM

Improvement of existing process		New for the firm, but not for your country		New for your country, but not for the world		New to the world	
	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent
1	57	41.01	24	58.54	13	61.9	3	42.86
2	42	30.22	10	24.39	3	14.29	3	42.86
3	13	9.35	1	2.44	2	9.52		
4	5	3.6	2	4.88	1	4.76		
5	7	5.04	2	4.88	1	4.76		
>5	15	10.8	2	4.88	1	4.76	1	14.29
Total	139	100	41	100	21	100	7	100

collected information on the firm's innovation in production and pro-
cesses. Using this information an innovation index was developed, for
both product innovation and process innovation. This index was fur-
ther discriminated on the basis of firms that collaborated/not col-
laborated with universities/PRIs, firms that used university or PRI as
sources of knowledge for new projects, and completion of existing
projects.

In the survey, the firms were asked to report product or process
innovation. Further, they were asked if the innovation was new to the
firm, new to the country and new to the world. Each of the categories
represents a higher degree of innovation, wherein the product new to
the world is a superior innovation to a product new to the country but
not to the world. A product new to firm but not new to the country is
inferior to innovation that is new to the country. Ordinal ranking from
1 to 5 were given for no innovation, innovation, new to the firm, new
to the country and new to the world. The number of products or
processes in each of these categories was also recorded. The firm's
innovation index calculated was:

$$IN_i = \sum r_{ij} n_{ij} / \sum n_{ij}$$
$$j: 1...5$$

where IN is the innovation index for the ith firm; r is the ordinal rank
given to the jth item and n is the number of innovative product/
processes for the jth item. The index is calculated for both product

TABLE 19
UNIVERSITY INDUSTRY INTERACTION AND INNOVATION

Types of firms by	Product innovation		Process innovation	
	Mean rank	Asymp. Sig	Mean rank	Asymp. Sig
Univ-Collaborating Firms	209.16		76.31	
Non Collaborating Firms	176.41	.027	84.14	.384
Firms using university suggestion as source of information for new projects	154.93		80.62	
Firms not using university suggestion as source of information for new projects	136.08	.091	79.28	.873
Firms using PRI suggestion as source of information for new projects	157.45		81.22	
Firms not using PRI suggestion as source of information for new projects	135.01	.039	79.62	.825
Universities contributing to Firms source of information for completing existing projects	156.52		78.23	
Universities not contributing to Firms source of information for completing existing projects	132.52	.037	76.21	.816
PRIs contributing to Firms source of information for completing existing projects	154.41		79.09	
PRIs not contributing to Firms source of information for completing existing projects	132.66	.044	76.38	.710

innovation and process innovation. We discuss the results below.

Firms that collaborated with universities/PRIs were found to have a higher mean rank of product innovation than compared to non-collaborating firms, implying these firms achieve a higher level of innovative ability. However such higher innovative ability is not observed in case of process innovation.

Regarding the use of university and PRIs as sources of knowledge in suggesting or contributing towards new projects and completion of existing projects, it was found that there was significant difference in the innovative ability of firms that used such sources of information when compared to firms that did not use such knowledge as sources of information (Table 19). Be it from PRIs or universities, and be it for suggesting new projects or for completing existing projects, those firms

that used such information were significantly more active in creating more product innovations. But none of these were significant discriminating factors when it comes to process innovation. Process innovation, thus seems to be less influenced by firms interaction with universities/PRIs than product innovation.

IX. Concluding Observations

Under the NSI framework of analysis universities and PRIs, being important sources of information and knowledge for firms seeking to enhance their innovative ability, are considered as key actors in the interactive process of innovation. This in turn is expected to rationalize the structure of universities and public funded research institutes towards their 'third mission' of successful and mutually beneficial interaction with firms. Most studies undertaken till now had been focused on understanding the dynamics of this process from the experience of the developed world. Yet, these processes may function differently within developing economies, because; *inter alia*, of the firm's dependence on imported technology, the generic nature and social embeddedness of universities. However with possible exception of a few studies, university industry interaction in India remains an unexplored area. This has motivated a study of the nature, charac- teristics and outcomes of university industry interaction in India as part of the IDRC sponsored project on this issue in Asia. The study was based on two surveys, one involving 460 firms and the other involving 735 professors/scientists employed in universities, technical colleges and public funded research institutes.

From the survey, it was observed that the firms are increasingly becoming R&D oriented probably because they are aware of the need to be innovative to survive in the competitive environment. About 14 percent of the firms were found not investing in R&D because they felt that R&D is too risky and costly. While large proportion of the firms claimed to have been involved in R&D, much of the innovations that they have claimed were local in nature. Firms in general opined that they were innovative, but the element of novelty in the innovative product/process was of limited meaning, confining mostly to novelty for the firm.

The Indian firms were found to be largely inward looking and depended mainly on its own manufacturing process, and customers as

the major sources of knowledge for innovation. The evidence in India suggest that neither universities nor PRIs have any important role as sources of information either in terms of suggesting new projects or help completing the existing ones. This finding is very much in tune with the studies in most economies, be it from the developed economies or from the developing economies.

Even the channels of linkages between firms and universities/PRIs are formalized channels and open channels. This does not confirm to the studies done in developed economies wherein the major channels of linkages were informal in nature, while formal channels were quite weak. The formal channels of linkages point to the structured and planned form of interaction in India rather than the organic and evolutionary nature of channels of linkages with the universities/PRIs in developed economies.

The incidence of interaction of firms with universities as reflected by the respondents to the survey is very low. Of the 462 firms that participated the survey only 11.27 percent claimed that they had any form of collaboration with a university or a PRI. For those who have interacted, the collaboration has been a success in terms of achieving the objective. On the other hand a large majority of the professors and scientists perceived that university-firm interaction was very important. More importantly, the professors felt that the extent of interaction has been increasing substantially over the years. Firms found their own internal sources sufficient for innovation. Moreover, cultural factors that governed the type of research conducted by both the universities and firms and the transactions costs involved in interacting with universities discouraged firms from interaction with the academia.

An analysis of the firm characteristics of the utilization of sources of information from universities/PRIs showed that firms with greater centralization and higher R&D intensity use of university/PRI as sources of information when compared to their counterparts. Thus sources of information from universities and PRIs acted as a complement to the R&D efforts taken by the firms. However, the link between the nature of R&D seem to be stronger with PRI in comparison to universities. This perhaps is reflective of the nature of R&D taken up both these institutions. While research undertaken by PRIs is more commercial in nature, the universities research is considered more 'basic' with lesser commercial value in it.

Older firms, larger firms and firms located in mega cities utilized the various sources of information more, both from universities and PRIs,

in comparison to other firms. However, there was no significant difference in firm characteristics in the degree of collaboration with universities/PRIs.

An analysis of the innovative outcome of the firms showed that firms that collaborated with universities/PRIs achieved a higher level of innovative ability in product. However such higher innovative ability is not observed in case of process innovation. Similarly, it was found that the innovative ability of firms that used sources of information from universities/PRIs was significantly higher when compared to firms that did not use such sources of information.

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References

Agrawal, A., and Henderson, R. "Putting Patents in Context: Exploring Knowledge Transfer from MIT." *Management Science* 48 (No. 1 2002): 44-60.

Anselin, L., Varga, A., and Acs, Z. "Local Geographic Spillovers between University Research and High Technology Innovations." *Journal of Urban Economics* 42 (No. 3 1997): 422-48.

Arundel, Anthony, and Geuna, Aldo. "Proximity and the Use of Public Science by Innovative European Firms." *Economics of Innovation and New Technology* 13 (No. 6 2004): 559-80.

Beise, M., and Stahl, H. "Public Research and Industrial Innovations in Germany." *Research Policy* 28 (No. 4 1999): 397-422.

Brisolla, Sandra Negraes. The Sad Story of Globalization: Reduction of University Industry Cooperation as a Result of Liberalization, Privatization and Government Cutbacks in Brazil. Paper Presented in the Third Triple Helix International Conference on Relations among Social Economic and Scientific Development in a Triple Helix of University-industry-Government Relations, Rio de Janeiro, April 26-29, 2000.

Caloghirou, Y., Tsakanikas, A., and Vonortas, N. S. "University-Industry Cooperation in the Context of the European Framework Programmes." *Journal of Technology Transfer* 26 (Nos. 1-2 2001): 153-61.

Carmines, E. G., and Zeller, R. A. *Reliability and validity assessment: Quantitative applications in the social sciences.* Beverly Hills,

CA: Sage, 1982.

Cockburn, Iain, and Rebecca, Henderson. "Absorptive Capacity, Co-authoring Behavior, and the Organization of Research in Drug Discovery." *Journal of Industrial Economics* 46 (No. 2 1998): 157-82.

Cohen, W. M., and Levinthal, D. A. "Innovation and Learning: The Two Faces of R&D." *The Economic Journal* 99 (No. 397 1989): 569-96.

_____. "Absorptive Capacity: A New Perspective on Learning and Innovation." *Administrative Science Quarterly* 35 (No. 1 1990): 128-52.

Cohen, W. M., Florida, R., Randazzese, L., and Walsh, J. "Industry and the Academy: Uneasy Partners in the Cause of Technological Advance." In Roger Noll (ed.), *Challenges to Research Universities.* Washington, D.C.: The Brookings Institution, pp. 171-99, 1998.

Cohen, W. M., Nelson, R. R., and Walsh, J. "Links and Impacts: The Influence of Public Research on Industrial R&D." *Management Science* 48 (No. 1 2002): 1-23.

Colyvas, J., Crow, M., Celijns, A., Mazzoleni, R., Nelson, R. R., Rosenberg, N., and Sampat, B. "How Do University Inventions Go Into Practice?" *Management Science* 48 (No. 1 2002): 61-72.

Eun, Jong-Hak, Lee, Keun, and Wu, Guisheng. "Explaining the University Run Enterprises in China: A New Theoretical Framework for University-Industry Relationship in Developing Countries and Its Application to China." *Research Policy* 35 (No. 9 2006): 1329-46.

Feldman, M. P. *The Geography of Innovation.* Amsterdam: Kluwer Academic Press, 1994.

Feldman, M., Feller, I., Bercovitz, J., and Burton, R. "Equity and the Technology Transfer Strategies of American Research Universities." *Management Science* 48 (No. 1 2002): 105-21.

Fontana, R., Geuna, Aldo, and Matt, Mireille. "The Driving Forces of University-Industry Collaboration." In Y. Caloghirou, A. Constantelou, and N. S. Vonortas (eds.), *Knowledge Flows in European Industry: Mechanisms and Policy Implications.* London: Routledge, 2004.

Hall, B. H., Link, A. N., and Scott, J. T. "Universities as Research Partners." *Review of Economics and Statistics* 85 (No. 2 2003): 485-91.

Harhoff, D. "Firm Formation and Regional Spillovers." *The Economics of Innovation and New Technology* 8 (No. 1 1999): 27-55.

Henderson, R., Jaffe, A., and Trajtenberg, M. "Universities as a Source of Commercial Technology: A Detailed Analysis of University Patenting, 1965-1988," *Review of Economics and Statistics* 80 (No. 1 1998): 119-27.

Jaffe, A. B. "Real Effects of Academic Research." *American Economic Review* 79 (No. 5 1989): 957-70.

Jensen, R., and Thursby, M. Proofs and Prototypes for Sale: The Tale of University In Licensing. NBER Working Paper No. 6698, Cambridge, MA, 1998.

Karlsson, C., and Andersson, M. The Location of Industry R&D and the Location of University R&D How Are They Related? CESIS Electronic Working Paper Series, Paper No. 38, Jönköping International Business School, Jönköping University, 2005.

Laursen, K., and Salter, A. Searching Low and High: Why do Firms Use Universities as a Source of Innovation? Paper Presented at the 3rd European Meeting on Applied Evolutionary Economics, Augsburg, Germany, April 10-12, 2003.

Liebeskind, J. P., Oliver, A. L., Zucker, L., and Brewer, M. "Social Networks, Learning and Flexibility: Sourcing Scientific Knowledge in New Biotechnology Firms." *Organizational Science* 7 (No. 4 1996): 428-43.

Lim, K. The Many Faces of Absorptive Capacity: Spillovers of Copper Interconnect Technology for Semiconductor Chips. MIT, Mimeograph, 2000.

Lööf, H., and Anders, Broström. Does Knowledge Diffusion between University and Industry Increase Innovativeness? CESIS Electronic Working Paper Series No. 21, The Royal Institute of technology, Available at http://www.infra.kth.se/cesis/research /publications/working papers, 2006.

Lundvall, B. A. (ed.). *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning.* London: Pinter Publishers, 1992.

Lundvall, B. A., and Johnson, B. "The Learning Economy." *Journal of Industry Studies* 1 (No. 2 1994): 23-42.

MacPherson, A. D. "Academic-industry Linkages and Small Firm Innovation: Evidence from the Scientific Instruments Sector." *Entrepreneurship and Regional Development* 10 (No. 4 1998): 261-76.

Mansfield, E. "Academic Research and Industrial Innovation: An Update of Empirical Findings" *Research Policy* 26 (Nos. 7-8 1998): 773–6.

Mansfield, E., and Lee, J. Y. "The Modern University: Contributor to Industrial Innovation and Recipient of Industrial R&D Support." *Research Policy* 25 (No. 7 1996): 1047-58.

Marotta, D., Mark, Michael, Blom, Andreas, and Thorn, Kristian. Human Capital and University-Industry Linkages-Role in Fostering Firm Innovation: An Empirical Study of Chile and Colombia. Policy Research Working Paper 4443, Washington, D.C.: The World Bank, 2007.

Mohnen, P., and Hoareau, C. What Type of Enterprise Forges Close with Universities and Government Labs? Evidence from CIS 2. MERIT-Infonomics Research Memorandum Series, August, 2002.

Meyer-Krahmer, F., and Schmoch, U. "Science-Based Technologies: University-Industry Interactions in Four Fields." *Research Policy* 27 (No. 8 1998): 835-52.

Nelson, R. R. "Institutions Supporting Technical Advance in Industry." *American Economic Review* 76 (No. 2 1986): 186-89.

Rosenberg, N., and Nelson, R. R. "American Universities and Technical Advance in Industry." *Research Policy* 23 (No. 3 1994): 323-48.

Saxenian, A. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128.* Cambridge, MA: Harvard University Press, 1994.

Schartinger, D., Schibany, A., and Gassler, H. "Interactive Relations between Universities and Firms: Empirical Evidence for Austria." *Journal of Technology Transfer* 26 (No. 3 2001): 255-69.

Shane, S. "Selling University Technology: Patterns from MIT." *Management Science* 48 (No. 1 2002): 122-37.

Stuart, T. E., and Shane, S. "Organisational Endowments and the Performance of University Start-ups." *Management Science* 48 (No. 1 2002): 151-70.

Thursby, J., and Thursby, M. "Who is Selling the Ivory Tower? Sources of Growth in University Licensing." *Management Science* 48 (No. 1 2002): 90-104.

Varga, A. "Local Academic Knowledge Transfers and the Concentration of Economic Activity." *Journal of Regional Science* 40 (No. 2 2000): 289-309.

Ziedonis, A. Inward Technology Transfer by Firms: The Case of University Technology Licences. University of California, Berkeley,

Mimeograph, 1999.

Zucker, L. G., Darby, M. R., and Brewer, M. B. "Intellectual Human Capital and the Birth of U.S. Biotechnology Enterprises." *American Economic Review* 88 (No. 1 1998): 290-306.