Aspects of Efficient University-Industry R&D Interaction: Implications & Requirements for Strategy Development

Subtheme (13.2): Management and capacity building for effective engagement in Triple Helix partnerships: challenges and possible solutions.

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Keywords:
University-Industry/Business R&D Interaction, Collaborative R&D, Joint R&D, Impacts of University-Industry R&D Collaboration.

Introduction:

In 2006, King Fahd University of Petroleum and Minerals (KFUPM) launched Dhahran Techno-Valley (DTV) with the aim of contributing instrumentally to building a future Saudi knowledge economy. Towards accomplishing this objective, KFUPM in collaboration with its giant neighbor, Saudi Aramco - world's largest oil producing company - managed to attract several multinational knowledge-based corporations to DTV. This brought many opportunities as well as several challenges and necessitated formulating university strategy for approaching future joint R&D involvements with the corporations. In this direction, this study represents an attempt to achieve a better organizational understanding about how modern universities worldwide effectively engage R&D activities with industries and businesses. Conclusions of this paper will assist KFUPM in laying a basis for future R&D interactions with industry in general and DTV corporations in particular. The paper globally investigates into R&D involvements of universities with firms for identifying the most common and innovative interaction modalities and also surveys outcomes of identified modalities and their impacts on university research productivity both quantitatively and qualitatively. Additionally, the study looks into the issue of type of joint research involvements and examines its relevance to the university original research identity. Lastly, the study defines the necessary conditions for implementing effectively the university-industry R&D interaction modalities.

State-of-the-art:

Engagements of universities and industries in effective triple helix arrangements which produce mutual benefits need proper interactional mechanisms that enable overcoming organizational and cultural barriers [1-2]. The open literature is full of specialized studies investigating into different aspects of university-industry R&D relations. Formulating strategic bases and platforms for university R&D alliances with industries requires defining proper modalities for interaction [3-5] and assessing impacts of joint R&D activities on research productivity and original research identity [6-15]. Other studies look into the proper mechanisms for equipping the university-industry alliances with suitable contractual arrangements, organizational commitments, specialized coordination, and formal evaluation procedures that enable the partners to initiate more explorative research, organize interdisciplinary projects with faculties in different research fields, and establish larger-scale R&D projects [1-2] & [16-19].

Methodology:

Developing a comprehensive university strategy for approaching R&D interactions with knowledge-based corporations requires answering specific questions that include (and not limited to): What are the most favorite modalities for industries/businesses to engage in R&D with universities? What are the impacts of these modalities on research activities of universities? For answering these questions, this paper globally investigates into the modalities of R&D involvements of universities with industry and surveys outcomes/impacts of these modalities on universities. Additionally, this paper attempts to answer a relevant question: Does the involvement of a university in joint research and developmental activities (with industry) imply any detrimental effects on the university original research directions? The approach followed to answer this question considers that involvement of universities with industries in joint R&D activities raises always questions/debate in regard to the forever entanglement of the two main university research types namely; the basic & the applied. Therefore, the study looks into more specific issues: Is it merely adequate to define the original research directions of a technical university as either pure basic or pure applied? What defines the original research directions of a technical university? Does a dichotomy really exist between the two main university research types; the fundamental curiosity-driven (pure basic) and the needs-driven (pure applied)? If yes, do other alternative research types exist? Addressing these questions is important because there are strong evidences that implications of current entanglement of basic and applied research terminology affects the way in which research decision makers of universities make explicit decisions about choices related to involvement in R&D with external partners and the relative volumes of fundamental and applied research.

Findings and interpretation:

Close look at recent reports and studies that analyze how firms worldwide undertake R&D activities tells that several changes have shaped companies' approaches over the last few decades. In his 2003 review for university-industry relations effectiveness, Richard Lambert (previous editor of *The Financial Times*) observed that the picture changed radically and long-established technology companies have found themselves under attack from different competitors on many fronts [19]. He added that companies that have only been in existence for few decades have sprung to global prominence, often by exploiting other people's research. The review also indicated that the reasons behind this are: 1) The increased complexity of technology products, which firms no more can manage by themselves, 2) The increased global competition forces companies to outsource growing proportion of their R&D, and 3) Needs, talents and capitals have all grown globally mobile. Klein et al. elucidated that collaboration between universities and industry intensified in recent years due to four interrelated factors: 1) The development of new, high-opportunity technology platforms such as computer science, molecular biology and material sciences; 2) The more general growing scientific and technical content of all types of industrial production; 3) The need for new sources of academic research funding created by budgetary stringency; and 4) The prominence of government policies aimed at raising the economic returns of publicly funded research by stimulating university technology-transfer [20]. To a large extent these factors intersect with the reasons mentioned in Lambert Review. An analysis for the R&D Magazine Awards over the period extending from 1971 to 2006 reinforced the idea that the U.S. innovation system changed in significant ways in recent decades and the collaboration between universities and industries has manifested itself prominently in these ways [21]. The analysis indicated that whereas the lion's share of the R&D 100 Award-winning U.S. innovations in the 1970s came from corporations acting on their own, most of the R&D 100 Award-winning U.S. innovations in the last two decades have come from partnerships involving business and government, including federal labs and federally funded university research. According to the analysis, most of the award-winning U.S. innovations started to involve some kind of inter-organizational collaboration, a situation that reflects the more collaborative nature of the innovation process and the greater role in private sector innovation by government agencies, federal laboratories, and research universities. Similar conclusions about the US innovation system can be drawn from outcomes of the 2008 US Innovation

Summit that gathered 23 chief technology officers of major US corporations [5]. The Summit noted that two broad trends are reshaping the way that world companies follow to undertake research around the world. The first is that they are moving away from a system in which most of their R&D was done in their own laboratories, preferably in secret, to one in which they are actively seeking to collaborate with others in a new form of open innovation. The second is that business R&D is growing global. The summit assuredly indicated that multinationals relocate their research centers in their most important markets, especially if those markets happen to contain centers of outstanding research. Their home country is no longer the automatic first choice for their R&D investment. A recent report for the UK Department for Business, Innovation and Skills indicated that the conduct of innovation is not only becoming more distributed, but it is also displaying signs of increased complementarities: inputs to the innovation process complement one another so that the total is more than the sum of its parts [22]. The report added that businesses rarely innovate in isolation, and often draw in information and knowledge collaboration and cooperation with universities and non-university institutes that engage in research and problem solving.

These observed changes in R&D capacities/capabilities of world companies and their rising trends for collaboration with others have been reflected on their approaches and modalities for interaction with universities and public research foundations. Many countries around the world have undertaken serious steps for benefiting from the growing university-industry mutual inclination towards conducting joint R&D. They established translational infrastructures to provide business-focused capacity and capability that bridges research and technology commercialization [22]. These organizations play a major role in combining a distributed system of knowledge and technology development and are frequently used in combination with other firms in the business sector in accessing knowledge for innovation [23]. Examples include the Fraunhofer Gesellschaft in Germany, ITRI in Taiwan, ETRI in South Korea, and TNO in the Netherlands, to name few. The Technology Innovation Centers represent a prominent example for such translational structures [24]. The network of Carnot Institutes in France was set up to link strongly the research systems with industry. In Belgium, the Inter-University Micro Electronics Centre was established for promoting R&D collaboration and developing technology skills with business. D’Este and Patel analyzed the extent to which knowledge transfer activities are spread across the academic community. They focused on the variety of channels of interaction and on the motivations for interacting with industry. Their Results showed that university researchers interact with industry using mainly five broad categories of interaction: creation of new physical facilities, consultancy and contract research, joint research, training, and meetings and conferences, each reflecting largely non-overlapping modes of interaction [14]. A comparative study that was conducted in four developed countries (US, UK, Canada & Japan) on university-business interactions showed that companies and universities interact to implement knowledge transfer projects in a rich variety of ways [4]. The analysis included in the study characterized nine different types of interaction into which the cases were classified, ranging from a license of technology offered by the university to use of the university's 'public space' by the company to develop its own contacts. The most popular modality in each country was collaborative or consortium research in which both the company and university were active in providing intellectual input to a research project (57% overall). This finding is associated with outcomes of Lambert Review which concluded that collaborative research is one of the most effective forms of knowledge transfer and the conclusions of Gulbrandsen and Smeby who pointed out that industrial funding for research activities in universities has become more related to collaborative mode of research [15]. A survey by Goddard and Isabelle asked 1800 directors of French public laboratories to estimate frequency of the principal modes of collaboration used between the laboratories and companies [3]. The key result, is that intellectual property - related knowledge and technology transfer through patent, software, and know-how license agreements occupies a distant second place compared to (in order of decreasing frequency): collaborative research, informal contacts, contract research, domestic and European research consortia, dissemination events such as seminars and conferences, and technical assistance. The survey showed that collaborative research is the most preferred modality for interaction. Another survey - conducted in Japan - indicated also that collaborative research is the most common form for university - industry engagements [25]. It was shown that nearly 80% of enterprises with more than 1001 employees (with university industry engagement activities) are involved in collaborative R&D with universities. Contracted research and provision of research grants follow. This wide adoption by the universities and private sectors in Japan for the collaborative R&D modality is attributed to the various systems established by the Japanese Ministry of Education, Science, Sports & Culture (Monbusho) since early 1980s, with the aim of maximizing the university's role in responding adequately to the diverse demands from the industry [26]. In the UK, income from collaborative research, as where there is a third partner from business or the community together with a public funder engaged with higher education institutions has risen by 12 per cent (between 2003-2007) to nearly £670 million [27]. Based on an overall assessment for the information available from several sources and reports on modalities of universities-industries interaction, it can be said that collaborative research is currently the most preferred modality worldwide for industries to interact in R&D with universities.

Identifying collaborative research as the most preferred modality for R&D interaction between industries and universities necessitates assessing the impacts of collaborative research on universities. Understanding reasons of both industries and universities to undertake in conjunction with each other certain knowledge and technology development and transfer projects is important for focusing light on consecutive outcomes. Industry's motivations and rewards have been carefully studied by Bozeman and Corely [28], Crespi et al. [29], Cockburn and Henderson [30] and Henderson et al. [31]. Typically, the reasons turn around: 1) Short-term considerations of applying technologies and 2) Longer-term ones revolving around increased absorptive and innovative capabilities. Close conclusions were reported by a study on firms' rationales for formalized interaction with two research universities in Sweden [32]. The study showed that firm interaction with universities seems to be a way to generate dynamic capabilities rather than to create outputs traditionally understood as innovations. Important mechanisms through which dynamic capabilities are generated include human capital management and increased access to academic networks. Furthermore, many firms enter formalized relations with university researchers in order to create internal abilities to recognize the value of external knowledge, assimilate it, and apply it to commercial ends. Results also suggested that for some firms, interaction with universities is a way to increase a firm's ability to translate market opportunities from these sources into opportunities. On the other hand, propensity of universities to collaborate with firms varies and is strongly related to: 1) the disciplinary focus of the university and the nature of its research activities [14] & [33-35] and 2) characteristics of the university individual researchers [14], [28] and [35]. D'Este and Perkmann investigated motives of academics to engage with industry using both informal collaboration and formal models of interaction [7]. Four main motivations were identified: commercial exploitation of technology or knowledge; informing academic research through engagement with industry; complementing public research monies with funding from industry; and using industry-provided equipment, materials and data for research. Results imply that most academics engage with industry in order to further their own research, either through learning or access to funds and other resources. In addition, commercialization on average was ranked lowest by the study survey respondents. The part of the study that focused on the incentives for academics from collaboration with industry showed that there is significant variation in terms of which incentive items researchers deem to be important. While 74.5% of researchers rated applicability of research as highly important, only 11.1% rated seeking intellectual property rights. The paper results also suggest the vision of entrepreneurial university fails to neatly capture the complex nature of academic researchers' interactions with industry. The study adds: "rather than a 'hybrid order' in which universities and industry converge to become common drivers of technological and economic development, most academic researchers are keen to retain their autonomy by ensuring that collaborative work with industry is conducive to – or at least compatible with – their research activity".

The built up understanding is that whenever proper conditions for a company to do research intersect with the natural character of a university, collaborative research opportunities arise. Richness of forms of collaborative research through which universities and industries can undertake joint research and work together helps in creation of these opportunities. Perkman and Walsh have shown that a four-fold typology exists for the university-industry collaborative projects according to degrees of project finalization as follows: problem solving, technology development, ideas testing and new knowledge generation [6]. Questions were asked for public lab directors to rate significance of different contributions from industry and frequency of various outputs from collaborations [3]. It is found that by far the most significant concerns are the funds for employing additional research personnel. This is followed in decreasing order by the provision of materials and samples, the suggestions of new research themes and the recruitment of students by industries. Further down in this list of inputs the development of technology transfer activities, the provision of datasets, access to equipment and instrumentation, the provision of know-how and methods, and researcher mobility towards the firms are encountered. When turning to the tangible outcomes, same study shows that collaborative R&D activities with industry have a tendency to essentially produce traditional outputs of research, i.e. publications and doctoral theses and these publications are generally co-authored, which would appear to reflect the dominance of collaborative research. However, it appears that technological artifacts, encompassing new products, new processes and software, are developed with about the same frequency, while outputs associated with the appropriation and exploitation of research results, patents, licenses of different kinds, and copyrights, show up only rarely.

Several studies looking into impact of collaborative research on quantity of university research can be found in literature. Godin and Gingras indicated that increase in funding from industry for R&D activities of Canadian universities and involvements of universities in intersectorial collaborations has not had any major deleterious effects on the scientific impact and number of papers [8]. For instance, the scientific production of universities rose 77.5% between 1980 and 1995, while at the heart of this activity, collaborations with partners increased by 155.2%, reaching 21% of publications. Gulbrandsen and Smeby found that the industrially funded collaborative mode of research is strongly correlated with high publication productivities, even when adjusting for types of publication and co-authorships and that academic publishing and commercial outputs are neither significantly positively nor negatively correlated [15]. Recently published reports and studies present quantitative analysis for the academic outcomes of collaborative research. Estanol et al. indicated that researchers benefit academically from collaborating with the industry [11-12] and researchers with no industrial involvement are predicted to publish less than those with a small degree of collaboration. Nevertheless, higher levels of industrial involvement affect negatively research productivity in terms of number of publications. They have indicated that university faculty is assumed to produce an average of 1.36 publication/year without any research funding and 1.57 publication/year with research funding with no collaboration with industry. The predicted publication rate of an academic with an average level of collaboration (1.78 article/year) is higher than that of an academic with no collaborative funding. But for slightly higher levels of collaboration, the predicted amount of publications turns out to be lower. At 38.5% of collaboration intensity, the predicted number of publications matches exactly the number for non-collaborative funding. If the percentage of the researcher collaborative funding is 81.8%, the predicted number of publications is lower than if the researcher had not received any grants in the previous 5 years. The papers concluded that encouraging universities to collaborate moderately with industry is a beneficial policy and useful also for academic productivity. But, discouraging high levels of industry collaboration is also advisable. However, this study has not indicated exactly what is meant (quantitatively) by a high level of university industry R&D collaboration and did not provide a measure for the percentage of research involvement beyond which the decline in research productivity starts to happen. For answering such a question, looking into another study by Freitas et al. may provide a basis for a preliminary judgment on the boundaries of high level collaborative research involvement [37]. This paper has indicated that researchers who interact with industry in a minor way (i.e. the return from this activity do not exceed 15% of the researcher’s budget) are more productive than those that do not collaborate with industry at all. The paper implicitly indicated that productivity of researchers start to decline beyond the 15% level of collaborative research involvements. Although the quantitative assessments of the studies by Estanol et al. [11-12] and Freitas et al. [37] were conducted on activities of researchers with different disciplinary backgrounds, combining their results could provide a starting basis for defining quantitatively the balanced levels of university-industry collaborations. Keeping balanced involvement levels of university researchers in collaborative research activities is a common conclusion for these studies. Wellings has provided empirical evidence on the relation between the collaborative research levels of universities and industries and academic and entrepreneurial outcomes [38]. He presented in a report - about the collaborative research benefits- data on the collaborative R&D income for 120 UK universities over 5 years (2002-2006) and the numbers of patents, IP income, PhD graduations and publications of these universities. The report indicates that there is a strong positive correlation between collaborative research, scientific papers in the citations databases, number of PhD graduates and patent activity.

Impact of collaborative research on university research quality has also been dealt with in several studies. Lebeau et al. presented an extensive literature review on the Canadian universities research collaboration with industry, from which they concluded that scientific impact of such research is not inferior to that of university research [13]. They showed that, although university-industry papers are published, on average, in journals with lower impact factors than papers originating from universities only; field-normalized citation values reveal that the average scientific impact of university-industry papers is significantly above that of both university-only papers and industry-only papers. They concluded that universities collaboration with industries is, thus far from detrimental to the scientific impact of university research and even increases it significantly. Perkmann and Walsh have pointed out that industry involvement of a university under certain conditions will benefit the production of scientific research and most likely the academic researchers will be able to exploit even the most applied industry projects to benefit their original research directions if such conditions are accomplished: condition 1: the researcher's discipline is associated with the sciences of the artificial; condition 2: the involved academics are highly research-driven and condition 3: the involved academics have a portfolio of different types of relationships with industry [6]. Klein et al. presented a study that dealt with the concerns that: 1- undue influence could exist by corporations that provide research funding, and potential abuse by faculty and university staff due to conflicts of interest, triggered by the lure of readily available money and conflicts of commitment, and 2- industry funded research is corruptive, especially in studies at university hospitals during drug development [20]. For dealing with the first argument, to minimize abuse, the study shows that universities have established rules for the use of time and laboratory by researchers for applied purposes. For the later argument, as the ethics debate was ongoing on the subject, many establishments have put in place rules for ethical behavior by researchers to avoid conflict of interest.

To address the issue of whether collaborative R&D can influence the original research directions of a university or not, this study followed a very fundamental approach. The approach focused on relevance of defining a research identity for a university to the decision making about the volume of research activities to be undertaken by the university in a certain direction, i.e. either fundamental or applied. This also implied the need to look into another associated aspect: does the involvement of universities and firms in joint R&D entail that the associated activities will be limited to applied fields? The main findings of this approach are summarized as follows:

1. *The traditional terminology for research types (applied and basic) may not be anymore adequate to describe the nature of university research activities or research involvements with external parties*:

   There are strong evidences that implications of current entanglement of basic and applied research traditional terminology is problematic and affects the way in which research policy makers should make explicit decisions about choices related to relative volumes of fundamental and applied research [6]. The first conclusion of the 2004 meeting at Ministerial level of the OECD's Committee for Science and Technology Policy underlined that the traditional linear view of innovation, from basic through applied research to development and application is no longer an adequate working model and the nature of the new ecologies has been captured in the phrase "Open Innovation" [37-40]. According to a study on the substantial uncertainties around how the volume and orientation of academic research in Sweden is measured, efforts are strongly needed for mapping the orientation of academic research to improve the academic research over categories such as curiosity-driven, strategic and needs-driven [17]. Isabelle indicated that three disentangled research directions exist namely; the nature of research activities, the intention of research and the norms of appropriation of research results and accordingly this could give rise to a new expanded taxonomy - for research types - that includes 27 different options for characterizing research activities [16]. The study notes that some research activities may move across the taxonomy as time passes, e.g. go from an essentially (curiosity driven - fundamental knowledge – open access) position to a more (use inspired - fundamental knowledge – proprietary) one. A process of iteration may also occur between the application and the existing fundamental research.

2. *No real dichotomy exists between applied and basic research – the continuous interplay between the two types is necessary for modern innovation systems*:

   Granberg and Jacobsson indicated that: 1) the argument that the belief that a dichotomy between curiosity-driven and needs-driven research types is misleading and these forms of research are complementary and 2) the funding directly available to academics in a technical university for exploratory, curiosity-driven work is virtually non-existent (as the researchers in technical universities tend always to orient their research efforts toward practical applications) [17]. Alike conclusions were reached by Teresa and Gray who showed that defining the extent to which university industry interactions involve either applied and basic research contents is an empirical matter whilst it is also recognized that by which technological knowledge fundamental understanding and applied research develop is an iterative process [4]. These findings are similar to what has been indicated by other references that a crucial property of the innovation system is the existence of two-way spillovers between basic and applied research [9] and [41]. Gersbach et al. gave several examples for how mutually applied and basic research impact each other [41]. They also pointed out that joint industry-university research centers could impact positively on basic research and that basic research might also benefit from applied research through increased patenting activities of university faculty.

3. *The understanding that involvement of universities with industries/businesses in research activities implies that the involvement will be dominated by applied activities is not true*:

   The aforementioned motivations of industry to do joint research with university which involve both short term projects related to applied technologies and long term ones around building innovative capacities, entails fundamentally that involvements of universities and industries may not be limited to a certain research type (specifically the applied research). Not only this, strong evidences exist that many of the most valuable R&D outcomes originate from collaborative R&D projects that are of basic nature. A 2010 study conducted by two investigators from both UK and Sweden indicated that several factors enhance innovation activities from basic research environments [39]. The study provided a model to explain how it could be possible to support ‘needs-driven research' and 'research-inspired innovation' from basic research. The most important conclusion of this study that it is possible for a modern university to become entrepreneurial in several ways while maintaining its basic research environment and identity. Another important finding for recent reports is that the most financial valuable outcomes resulted mainly from basic and fundamental research. An analysis of the distribution of financial returns from the licensing and spin-out case studies from Russell Group universities (top 20 UK universities) shows that the vast majority of the value returned over time - from research commercialization activities - originated from more fundamental and basic research [43]. The analysis also indicates: whilst the differentiation between basic and more applied research is becoming increasingly less relevant, an analysis undertaken for 125 case studies collected from Russell Group universities using the standard definitions of research showed that basic, curiosity-driven research has led to some of the most significant returns to the UK economy and society arising from our case studies. Of the top ten projects, measured by financial returns, eight were the products of basic research. Findings of this report indicate that the research funding system should allow space for fundamental basic research, complemented by strategic priority programmes and incentives for researchers to work on projects focused on application. It is also needed to find ways of combining these two approaches, to bring together public and private funding and research talent to work on major research challenges with major societal impact. The collaborative research with industry seems to provide the most convenient platform for this implementation. These findings fit with the outcomes of a research that addressed the challenges and opportunities for the UK science base. Balance, flexibility and strategic oversight in funding basic research has been considered as one of the main vision factors [11]. In presenting this vision, the UK Department for Education and Skills indicated that research can be considered along two orthogonal axes, representing consideration of use and the quest for fundamental understanding [44]. This is illustrated in the frontspiece of the framework report to reflect the strategic understanding for the applied-basic research entanglement issue.

The last part of this study looked into whether articulated good practices and frameworks exist or not for organizing the collaborative R&D activities between universities and firms. The main outcomes of this part could be summarized as follows:

1- Perceptions of realized mutual benefits are important for effective behavior of partners throughout research collaboration [2]. However, because universities, companies and public research organizations come from different traditions and exist to serve different purposes, the need for close understandings prior to and during collaborative R&D involvements become more evident and needed [36]. Therefore, it is important that these traditions are understood in order that the reasons for working together can be identified and objectives set out and managed.

2- Formal R&D relations, where universities and firms signal commitment to the collaborative effort provide the most successful type of linkage through which the main direct influence of science on the economy is realized [45-46]. It seems that the collaborative R&D agreements provide convenient platforms for reflecting the understandings between the two sides.

3- Good practice models exist for defining: a) components of formal agreements for university-industry R&D collaborations and b) management practices for collaborative R&D projects. The report on a special conference about the effective collaborative R&D presented findings that would be actionable by universities and companies [36]. The conference outcomes summary included list of guidelines for managing effectively the university industry collaborative R&D , where the conference workbook included tables setting out some identified principles, barriers and possible ways of overcoming the barriers for collaborative R&D. Lambert Review has included several designed models of collaborative research with Industry based on two parties (collaboration) and multiple parties (consortium) [19]. The collaboration agreement (between two parties) has 5 model agreements. The aim of the model agreements is to maximize innovation. The cornerstone of the five model research collaboration agreements is that, at the least, a commercial sponsor should have the right to use the results on a non-exclusive basis so as to promote the use of the results and therefore innovation. The model agreements have not been developed with the aim of maximizing the commercial return to the universities; the aim is to encourage university and industry collaboration and the sharing of knowledge. They do not represent an ideal position for any party; depending on the circumstances they are designed to represent a workable and reasonable compromise for both or all parties. The Lambert report on university – industry collaboration has been reviewed by all the major British universities, international businesses and consultations, professional and trade bodies and has been widely accepted in UK as the best practice model for implementing university – industry collaborative research. Tina et al. presented a good practice model for university-industry collaboration management [2]. Their research examined and discussed the main issues and important success factors to emerge from both the published literature and evidence drawn from six case studies, each examples of university industry interaction on R&D projects. The good practice model presented as a result of this research is based on six key areas, representing the major common themes to emerge from the multi-case study and the published literature: 1) the need to evaluate new partners and build a collaborative environment which takes into account any key issues identified, 2) good project management is essential to success, and particular emphasis should be given to structured objective setting, good progress monitoring, effective communication and deploying only trained, high quality project managers to run the collaboration, 3) a tendency for collaborations to be influenced by external factors such as corporate instability, indicates that the management processes themselves need to be flexible enough to cope with change, 4) the importance of trust, commitment and continuity was reinforced by this research. Further, important insights were gained into preparing the ground for successful collaboration, 5) effective management of university–industry interactions must include measures which will help maintain the interest and commitment of the industrial partners and 6) good university–industry relations require that an appropriate balance be achieved between academic objectives and industrial priorities.

Conclusions:

Findings of the study presented in this paper show that: 1) collaborative R&D is the most preferred modality for firms to interact in R&D with universities and 2) there are many indications that involvement of university researchers in balanced collaborative R&D activities has positive effects and industry R&D interaction enhances their research productivity (both quantitatively and qualitatively). Recent studies show that regardless of the university-industry R&D involvement type, under certain conditions the collaboration will benefit the production of scientific research and most likely the academic researchers will be able to exploit even the most applied industry projects to benefit their original research directions. It is also possible for basic research universities to maintain their identity while exploiting commercially the entrepreneurial outcomes of their joint R&D outcomes with industry as there are several factors enhancing innovation activities from basic research environments. Models exist for explaining how it could be possible to support ‘needs-driven research’ and ‘research-inspired innovation’ from basic research. In regard to the type of joint research involvements, the study shows that this subject is multi-dimensional and defining university research type as either pure basic or pure applied is an oversimplification and may reflect non-realistic/non-practical approach. Although it can be concluded that the decision making of a university about its involvements in joint R&D with firms should not be strongly associated with nature of the intended research, collaborative research seems to provide a very convenient platform for allowing space for fundamental and basic research. Good practice models exist for managing the university-industry R&D collaborative R&D activities. These models include the need for defining criteria to evaluate new industry partners and measures which will help maintaining the interest and commitment of the partners. Special attention should be given to the proprietary benefits, ensuring benefit at least commensurate with investment, and planning for the achievement of tangible outcomes early in the project. For avoiding non-favorable impacts that could emerge from joint R&D engagements with industries and for responding to the arguments that research commercialization and collaboration may have undue influence on their original research direction, universities respond not by abstaining from getting involved in research collaboration but rather by dealing with these arguments to minimize abuse if exists. Universities need to establish institutional paths for the collaborative research-based innovation and implement available good practice models for university-industry collaboration management.

Future research Directions:

Some of the issues discussed in this paper can be considered as broad and commonly applicable to university-industry R&D collaborations. More specialized research is needed to explore how good practice models can be finely tuned to capture specifically defined collaborative needs of academia and business. Discipline-wise quantitative assessments for the impacts of collaborative R&D activities are needed. Future research needs to focus on verifying findings of this paper through case studies involving universities and industries that are actually engaged in specific collaborative R&D projects. Empirically-based research is needed to better understand the impact of collaborative R&D at the project level on both academia and industry. Academic and research standing of universities that are heavily involved in collaborative R&D with firms and industries is another direction for future investigations.

References:

1- Kyoung-Joo Lee, From Interpersonal Networks to Inter-Organizational Alliances for University–Industry Collaborations in Japan: the Case of the Tokyo Institute of Technology, R&D Management, Volume 41, Issue 2, pages 190–201, March 2011.

2- Tina Barnes, Ian Pashby and Ann Gibbons, Effective University –Industry Interaction: A Multi-case Evaluation of Collaborative R&D Projects, European Management Journal, Vol. 20, No. 3, pp. 272–285, 2002.
3- John Gabriel Goddard and Marc Isabelle, How do Public Laboratories Collaborate with Industry? New Survey Evidence from France, Working Paper IMRI, 2006/02.
4- Philip Ternouth, Cathy Garner, Marcel Mongeon, Jeff Cope, Robert Kneller, University-Business Interaction: a comparative study of Mechanisms and Incentives in Four Countries Cross-Cutting Review CROSS Report to Sasakawa Peace Foundation March 2009, Published by Council for Industry and Higher Education.
5- Chief Technology Officers Innovation Summit: Meeting Summary Assuring U.S. Innovation Leadership in the Twenty-First Century Finance and Strategy, Research & Technology Executive Council, December 2009.
6- Markus Perkmann and Kathryn Walsh, The Two Faces of Collaboration: Impacts of University - Industry Relations on Public Research, Kathryn Walsh Forthcoming in Industrial and Corporate Change (2009). Work supported by the 'Innovation and Productivity Grand Challenge' (IPGC), an initiative of the Advanced Institute of Management Research (AIM) funded by the UK's EPSRC (EP/C534239/1).
7- Pablo D'Este and Markus Perkmann, Why Do Academics Engage with Industry? The Entrepreneurial University and Individual Motivations, Advanced Institute of Management Research, Research Paper Working Research 2010.
8- Benoît Godin and Yves Gingras, Impact of Collaborative Research on Academic Science and Public Policy, volume 27, number 1, February 2000, pages 65–73, Beech Tree Publishing.
9- Sooho Lee and Barry Bozeman, The Impact of Research Collaboration on Scientific Productivity, SAGE Publications, November 2010.
10- Behrens, Teresa R. & Denis O. Gray (2000), Unintended Consequences of Cooperative Research: Impact of Industry Sponsorship on the Climate for Academic Freedom and Other Graduate Student Outcomes, Research Policy 30(2): 179–99.
11- Albert Banal-Estanol, Mireia Jofre-Bonet and Cornelia Meissner, The Impact of Industry Collaboration on Academic Research Output: A Dynamic Panel Data Analysis, September 2009, Research Project Financed by the Pump Priming Fund at City University and ESRC Research Grant RES-000-22-2806.
12- Albert Banal-Estanol, Mireia Jofre-Bonet and Cornelia Meissner, The Impact of Industry Collaboration on Research: Evidence from Engineering Academics in the UK, August

2010. Research Project Financed by the Pump priming fund at City University and ESRC research grant RES-000-22-2806.

13- Louis-Michel Lebeau, Marie-Claude Laframboise, Vincent Larivière and Yves Gingras, The Effect of University-Industry Collaboration on the Scientific Impact of Publications: the Canadian case (1980-2005), Observatoire des sciences et des technologies (OST), Centre interuniversitaire de recherche sur la science et la technologie (CIRST), Université du Québec à Montréal, CP 8888, Succursale Centre-ville, Montréal, Québec, H3C 3P8.

14- P. D'Este and P. Patel, University - Industry linkages in the UK: what are the factors determining the variety of interactions with industry? SPRU-Science & Technology Policy Research, July 2005.

15- Magnus Gulbrandsen and Jens-Christian Smeby, Industry Funding and University Professors' Research Performance, Research Policy 34 (2005) 932–950.

16- Marc Isabelle, Proprietary vs. Open-Access Dimension of Knowledge: Illustration in a Large Public Research Organization, Genesis of Innovation, Edward Elgar Publishing, 2008.

17- Anders Granberg and Staffan Jacobsson, Myths or reality – A Scrutiny of Dominant Beliefs in the Swedish Science Policy Debate, Science and Public Policy, Volume 33, number 5, June 2006, pages 321–340.

18- Stokes D.E., (1997), Pasteur's Quadrant: Basic Science and Technological Innovation, Washington D.C.: Brookings Institution Press.

19- Lambert, R. (2003), Lambert Review of Business-University Collaboration. Final Report. HM Treasury. London, UK.

20- Raphael Klein, Uzi de Haan and Albert I. Goldberg, Overcoming Obstacles Encountered On the Way to Commercialize University IP, J Technol Transf (2010) 35:671–679.

21- Fred Block and Matthew R. Keller, Where Do Innovations Come From? Transformations in the U.S. National Innovation System, 1970-2006, The Information Technology & Innovation Foundation, July 2008.

22- A Report by Dr. Hermann Hauser, The Current and Future Role of Technology and Innovation Centres in the UK, Department for Business, Innovation and Skills, First published March 2010.

23- Mina, A., Connell, D. and A. Hughes, 2009, 'Models of Technology Development in Intermediate Research Organisations', CBR Working Paper no. 396, University of Cambridge.

24- OECD policy brief, Economic Survey of Spain 2007, OECD, Paris, January 2007.

25- Kazuyuki Motohashi, Economic Analysis of University-Industry Collaborations: The Role of New Technology Based Firms in Japanese National Innovation Reform, January 2004, RIETI Discussion Paper Series 04-E-001.

26- Jiang Wen and Shinichi Kobayashi, Exploring collaborative R&D network: Some New Evidence in Japan, Research Policy 30 (2001) 1309–1319.

27- UK Higher Education – Business and Community Interaction Survey, July 2008/22 Policy development Report on survey.

28- Bozeman, B. and Corley, E. (2004) 'Scientists' Collaboration Strategies: Implications for Scientific and Technical Human Capital', Research Policy 33: 599-616.

29- Crespi, G., D'Este P., Geuna A. and Fontana R. (2010) 'The Impact of Academic Patenting on University Research and its Transfer', ICER Working Paper Series, N: 01-09, 2009.

30- Cockburn, I.M. and R.M. Henderson (1998), "Absorptive Capacity, Coauthoring Behavior, and the Organization of Research in Drug Discovery," Journal of Industrial Economics, Volume 46, pages 157-182.

31- Henderson, R., A.B. Jaffe and M. Trajtenberg (1998), "Universities as a Source of Commercial Technology: A Detailed Analysis of University Patenting, 1965–1988," Review of Economics and Statistics, Volume 80, pages 119-127.

32- Anders Broström, Firms' Rationales for Interaction with Research Universities and the principles for public co-funding, February 2008, Paper No. 115-Electronic Working Paper Series, CESIS (Swedish Institute for Studies in Education and Research (SISTER) and CESIS.

33- Bekkers, R. and Bodas Freitas, I.M. (2008), Analyzing Preferences for Knowledge Transfer Channels between Universities and Industry: To What Degree Do Sectors Also Matter? Research Policy, 37: 1837-53.

34- Klevorick A.K., Levin, R.C., Nelson, R.R. and Winter, S.G. (1995) 'On the Sources and Significance of Inter Industry Differences in Technological Opportunities', Research Policy, 24: 185-205.

35- Cohen, W.M., Nelson, R.R. and Walsh, J. (2002) 'Links and impacts: The influence of public research on industrial R&D', Management Science, 48(1): 1-23.

36- D'Este, P. and Patel, P. (2007), University–Industry Linkages in the UK: What are the Factors Underlying the Variety of Interactions with Industry? Research Policy, 36: 1295-1313.

37- Isabel Maria Bodas Freitas, Aldo Geuna and Federica Rossi, University-Industry Interactions: The unresolved puzzle, Working Paper Series, Paper No. 09/2010, Department of Economics, Italy.
38- Paul Wellings Vice-Chancellor Lancaster University, A Report Prepared for the Rt. Hon. John Denham, MP, Secretary of State for Innovation, Universities and Skills- Intellectual Property and Research Benefits, 30 September 2008.
39- Report on A Special Conference Brussels, 5-6 February 2004 Partnering: Effective Collaborative R&D and Knowledge Transfer, Copyright © The European Industrial Research Management Association.
40- Final Communiqué, Meeting of the OECD Committee for Scientific and Technological Policy and Ministerial Level: Science, Technology and Innovation for the 21st Century (2004), OECD, Paris.
41- Hans Gersbach, Gerhard Sorger and Christian Amon, Hierarchical Growth: Basic and Applied Research, Working Paper 09/118, August 2009, Economics Working Paper Series, Swiss Federal Institute of Technology Zurich.
42- Fumi Kitagawa and Caroline Wigren, From Basic Research to Innovation: Entrepreneurial Intermediaries for Research Commercialization at Swedish 'Strong Research Environments', Paper no. 2010/02, Centre for Innovation, Research and Competence in the Learning Economy (CIRCLE), Lund University-Sweden.
43- The Economic Impact of research conducted in Russell Group Universities Russell Group Papers – Issue 1, 2010
44- Science & Innovation Investment Framework 2004 – 2014, Department for Education and Skills, July 2004.
45- Kaufmann A., F. Tödtling (2001), Science-Industry Interaction in the Process of Innovation: The Importance of Boundary - Crossing. Between Systems, Research Policy, Vol. 30, pp. 791-804.
46- Adams, J. D., E.P. Chiang and J.L. Jensen (2003), The Influence of Federal Laboratory R&D on Industrial Research, The Review of Economics and Statistics, Vol. 85, pp. 1003-1020.