MANAGING RESEARCH COLLABORATIONS AS A PORTFOLIO OF CONTRACTS: A RISK REDUCTION STRATEGY BY PHARMACEUTICAL FIRMS

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Managing Research Collaborations as a Portfolio of Contracts: A Risk Reduction Strategy by Pharmaceutical Firms

Abstract: *This paper presents an empirically derived model of the process through which firms facing high R&D risks and costs, leverage their limited R&D resources, by contracting out upstream (laboratory scale) research at low cost for a portfolio of R&D projects to not-for-profit technology institutions. They then concentrate their resources on downstream (commercial scaleup) research utilizing the limited set of successful upstream research outputs received from their collaborators. This risk reduction strategy is adopted by pharmaceutical firms which typically face both intense new product competition as well as high failure risks in upstream research. The process model has been developed by drawing from and synthesizing in-depth project case studies of pharmaceutical firms. Apart from contributing to theory, this model can enable practitioners in both firms and technology institutions to understand effective processes required for initiating and implementing such a strategy for mutual benefit.*

Key Words: process model, research collaborations, technology institutions, pharmaceuticals, portfolio, managing risk.

Introduction

Pharmaceutical firms are a sharp example of technology based firms that face intense new product competition as well as high risks in new product development research. To survive in the pharmaceutical industry, firms have to release a stream of new products rapidly, even though usually only a small fraction of their new product development projects are successful. New product development costs, specially in upstream research (or basic research) are extremely high and often beyond the reach of any but the leading firms in the industry.

In such a competitive environment, pharmaceutical firms with limited internal R&D resources and lacking the financial resources to invest in developing an adequate R&D infrastructure, have leveraged their limited R&D resources by contracting out upstream (laboratory scale) research for a portfolio of R&D projects to not-for-profit technology institutions (TIs) [1]. They then concentrate their limited R&D resources on downstream (commercial scaleup) research utilizing the limited set of successful upstream research outputs received from their collaborators. This strategy allows these firms to exploit the facilities and expertise available at several TIs to rapidly implement upstream research for several potential new products at a comparatively low cost. It also allows the firm to retain the secrecy and proprietary knowledge developed during downstream research by conducting it entirely within the firm. Projects implemented with several TIs as a portfolio of contracts can effectively reduce the overall new product development risk for the firm and also help technology institutions in utilizing their resources for the industry.

Lee, Bae and Lee [2] consider such research collaborations between firms and TIs as "vertical" collaborations as there is an implicit division of labour between the TI (upstream research) and the firm (downstream research). A vertical collaborative R&D contract with a TI arises when the firm approaches the TI with a technological problem (and the TI accepts it) for which (a) the TI has no readily transferable solution or access to such a solution, (b) the TI and firm both have complementary expertise and capabilities required to solve the problem, (c) the R&D work is sequential, with the initial (upstream) laboratory scale process research being at the TI, and the later (downstream) research for scaling up the laboratory scale process for commercial scale production being at the firm.

This paper presents a model of the process through which a firm initiates and implements a portfolio of vertical collaborative R&D contracts, in which TIs concentrate on upstream research, transfer the technology to the firm, and the firm then concentrates on downstream research. The model traces the web of interlinked project processes and indicates their anticipated impacts on firm and TI activities. The model has been developed by drawing from and synthesizing in-depth project case studies of pharmaceutical firms.

Literature Review

Dodgson [3] defined technological collaboration as any activity where two or more partners contribute differential resources and technological know-how to agreed complementary aims. The essential difference between university or TI research, and industrial research, is that university research is largely basic in nature, while industrial research is largely of shorter-term, problem solving, design and development nature [4]. Bonaccorsi and Piccaluga [5] identified from an extensive literature review that technology based firms enter into relationships with TIs for four basic reasons: (a) to get access to scientific frontiers, (b) to increase the predictive power of science, (c) to delegate selected development activities and (d) to compensate for lack of resources. However the strategy of firms, in implementing a portfolio of contracts for upstream research with TIs in an attempt to get rapid results with reduced costs and risks, while concentrating their limited R&D resources on downstream research, has not been specifically identified or described in the literature.

Some studies however do give indications of this strategy. Technology driven firms have been found to increasingly use a variety of collaborative arrangements, for direct access to new technologies [6]. Bower [7] found that over a period of 10 years the proportion of R&D projects sourced elsewhere by major American and European drug companies went from 4% to 29%. Whittaker and Bower [8] show that in the pharmaceutical industry of developed countries there is a clear shift to external alliances for product development due to high R&D costs and low success rates. Studies in this area have however concentrated more on firm to firm collaborations than university or TI-firm collaborations. Though literature on technological collaboration in the university -firm or TI-firm context exists (e.g. Bird, Hayward and Allen [9]; Bonaccorsi and Piccaluga [10]; Bower [11]; Berman [12]; Lopez-Martinez et.al. [13]; Rosenberg and Nelson [14]), the focus of these studies, according to Bailetti and Callahan [15] 'have been on the strategy and the reasons for entering a collaboration rather than its management.' According to Alter and Hage [16] 'there are no studies of problem solving in collective research involving multiple business firms and universities.'

As previous research has largely concentrated on identifying the antecedent conditions for initiating TI-firm collaborative activity and their consequences, there is a lack of adequate empirical research which gives insights into the *process* of managing such activity. Further there is no clear theory linking the identified antecedent conditions to the process of managing the collaboration and its identified consequences. This research attempts to fill this gap by developing an empirically based model of one type of TI-firm collaborative research activity - the process of initiating and implementing a portfolio of vertical TI-firm collaborative research contracts by pharmaceutical firms.

Methodology

Given the research gap identified and the lack of adequate process research in this area, it was necessary to conduct a process study, using qualitative research methodology, to build an empirical base for theory development. Process questions are essentially of *the how did it happen?* nature but they also include the *what happened?* and *why did it happen?* questions relevant to the context of the study. Grounded theory building [17] using the case study method [18] is considered an appropriate and valid [19] approach for studying process issues [20]. The longitudinal processual method of case research [21] was adopted as it answers the *what?, why?* and *how?* questions together within a relatively short research time span.

Multiple qualitative project case studies of pharmaceutical firms adopting this approach were developed in this research. Multiple cases provide greater scope for attempting analytical generalisation [22] compared to a single case and provide a useful vehicle for understanding the complexity and richness of the project initiation and implementation process, considering the paucity of previous work. A variety of cases were chosen in an effort to develop richer theory and provide an opportunity for replication and comparison, thus building external validity [23] and expanding the domain of generalisation [24].The broad research approach adopted was in the holistic tradition [25] of strategy process research in attempting 'to track simultaneously over time, multiple contextual factors, strategies, decision processes, administrative systems and outcomes' while focusing on a 'narrow strategic problem'. This approach has not been adopted for research in multi-organisational contexts so far, but is recommended [26].

The data collection was primarily through in-depth semi-structured and open-ended interviews of key project participants in multiple hierarchical levels and departments in both organisations. As far as possible, all project participants were interviewed, some repeatedly, for varying periods from about an hour to two and half hours. The process questions raised in the interviews traced the project process from inception to completion. Apart from this, information was sought from participants on their organisations, the relevant industry, and the environment faced by the firm and the TI. Other topics covered were: the importance of the project's product category to the firm; governance structure of the project; characteristics of the project and technology which affected project implementation; problems encountered and their resolution; monitoring of projects; meetings; co-ordination; communication; capability development; and changes in plan over the duration of the project. As the attempt was to gather as much of the richness of the project process as possible, new topics which emerged during the interviews were opportunistically explored, and new questions were added for subsequent interviews [27].

Participants mentioned their background and experience, areas of professional interest, the history and experience of their interaction with firms or TIs and its importance. They were also asked to describe and evaluate: their individual role in the project; formal and informal relationships; help given and received; technology transfer and training; uniqueness of the project; learning from the project; and the project's likely impact on their organisations in both technical and managerial spheres. The interview schedules also covered the non-project routine activities of project participants and its impact on their involvement in the project. Based on the respondent's answers, and if additional information was necessary, probing questions were asked. The open ended questions gave respondents considerable leeway in giving descriptive answers and elaborating wherever necessary.

Participants were also asked to assess the success or failure of the project, to give their opinion on its likely causes and suggest possible improvements. They were also requested to suggest what firms and TIs could do to facilitate such projects and to develop long term relationships. Apart from their content, these suggestions and opinions also gave useful insights into aspects of the project process which were not elicited through direct questions. Interviews were completely transcribed. Interview data was supplemented by observations, communications, records and reports [28]. Through the multiple projects, themes and issues gradually re-occurred and over the set of projects there was repetition of process details indicating that theoretical saturation had been reached. When sufficient repetitions occurred to ensure external validity [29] no further projects were studied.

The Miles and Huberman [30] 'categorisation and theme analysis' technique was used to develop cases from the interview and background data. First, the background data and the interview statements in each transcript were thematically classified. Based on this classification, a common case writing format was developed with a logical and chronological sequence for presenting the data. All transcripts related to a project were then combined within this common format. The various sections were then logically connected and edited to facilitate readability. The common format ensured reliability in the data collected and also provided within case analysis [[31]]. While structuring the cases, the focus was on the development of causal patterns over time within cases and on the development of patterns across cases. This analysis served as inputs for the inductive development of the proposed process model. The project case studies traced the life of the project from conception to completion. Draft cases were read, corrected and cleared by the firm in consultation with the TI.

Eisenhardt [[32]] has presented a framework for building theory using case study research. This research is set in Eisenhardt's framework. Steps on selection of cases, crafting data collection instruments, entering the field, analysing data, shaping hypothesis and reaching both case and research closure, closely followed this framework. Since all cases could not be equally well developed due to differences in the background and interview information made available to the researcher, therefore in the analysis, some cases developed into central cases contributing to the development of generalisations, while other less developed cases supported the generalisations built from the central cases. As this research was of an exploratory nature, it stopped after using the empirical base to identify the project process and to conceptually build on it in developing a proposed theory in the form of a process description and model. Further research is required for testing the adequacy of the variables included in the process model and the completeness and accuracy of the process description and model.

Process Description and Model

The process model presented in Figure 1 and the general process description presented in this section are synthesized from those TI-firm collaborative research project cases developed as described in the methodology section above, where: (a) the firm contracted out the upstream (laboratory scale) research part of the project to a TI which implemented it independently, (b) if the TI succeeded in developing the basic laboratory scale product or process, the firm took a technology transfer of the basic product or process in a one time intensive interaction, and (c) the firm subsequently worked independently on the downstream (commercial scaleup) research part of the project.

The general description of the project process is in the form of a set of interconnected proposition like statements covering: (a) the project antecedent conditions and project initiation process, (b) the project implementation and learning/transfer process, and (c) evaluations across organizations and perceived consequences of the project. Important aspects of the process description are summarized at the end of the description in two tables - Table 1 which covers the project antecedent conditions and joint project initiation process; and Table 2 which covers the project implementation, learning from the project and evaluations across organizations.

Figure 1 about here

Project Antecedent Conditions and the Joint Project Initiation Process

The project antecedent conditions, the firm's project implementation mode choice process, and the joint project initiation process are described in this section. Interspersed with the description, pertinent examples and quotations drawn from two of the cases are presented in *italics* to illustrate some important aspects of the process description. Examples from FDC and SUN -- two small pharmaceutical firms which collaborated with several TIs such as IICT - a not-for-profit government pharmaceutical and chemical laboratory, UDCT - an autonomous university pharmaceutical and chemical department and BCP - a college of pharmacy, for developing several products including bulk drugs, formulations and fermentation products -- are followed through in the subsequent sections also.

Importance of the Project for the Firm: The project is of commercial [[33]] rather than strategic [[34]] importance to the firm and often one of a stream of projects being undertaken by the firm. While the portfolio of projects is important strategically, individual projects are seen only as part of a portfolio. Maintaining a reasonable success rate in the portfolio is important to keep pace with the other firms in the industry.

This is shown in the SUN case. For SUN, the projects were routine - part of their planned portfolio of projects. Said a project leader at SUN - "We started our R&D centre two to three years back. Meanwhile we needed completed projects which would *be immediately transferred to the plant before our centre could come up full time. So we went to IICT for the immediate technology.". SUN contracted upstream research for several projects to the TIs and once they got the basic laboratory level process, they started on the scale up of the technology to the pilot plant stage and then the commercial plant stage.*

Technology Involved in the Project: The technology area in which R&D is required for the project is familiar to the firm but the firm lacks or cannot spare its resources for the upstream research required. The basic technological approach is not new. The project requires incremental and often repetitive experimental refinement of technology for developing the product or process with the end result being a patentable new product or process.

In the SUN case, the upstream research involved in the projects could have been carried out within the firm by SUN if it had the equipment, time and manpower at the time the projects were initiated. The projects involved the development of viable routes for bulk drugs through experimental research but did not represent any new technological development.

Options for the Firm: For each project in its portfolio, the firm typically explores three alternatives: (a) *Contract R&D fully to outside firm or TI.* This has secrecy leakage problems, is very expensive, has high risk, gives low opportunity for learning and leads to no capability building. On the other hand it involves one time payment and low internal investment. (b) *Acquire additional manpower and equipment and do the entire project within the firm.* While this has no secrecy leakage problems, it is time consuming, very expensive, has high risk and requires high internal investment. (c) *Contract a TI for upstream research and conduct downstream R&D entirely within the firm.* This requires lower investment, is more rapid, is low in cost and has lower risk. There is also higher confidence in the TI doing only upstream research successfully compared to it doing the entire project successfully as in the first option. A firm can take the first option if secrecy is not a major issue and the TI has the capability and willingness to handle downstream R&D also. It takes the third option to maintain secrecy and apply proprietary in-house skills for downstream R&D to develop a viable product or process. Here we consider the case where the firm decides to choose the third option. While leveraging its R&D facilities in this manner, the firm usually retains the more secretive and important projects for internal development, and contracts out the less secretive and less important ones to TIs.

This choice argument and analysis is shown by statements of a project leader from FDC: "Earlier we used to develop products on our own. This meant that we spent a number of years for basic work (e.g. literature review on patents), then moved to pilot plant stage and finally to the production plant level. This took a longer period of development but on the positive side secrecy was maintained. Then two to three years back the government gave some incentives for sponsoring projects with technology institutions. We are aware of the good work being done by UDCT, NCL and IICT in these areas. Students from these institutes are also joining us so we are aware of the facilities and expertise available in each institute. Considering all these, we decided to give some projects to these institutes. Though there are secrecy clauses (in the contract), we cannot have secrecy of the level of doing it ourselves. But benefits are substantial when we go to TIs. There is a risk but it is acceptable. We can get the process at a price but bringing it to commercial scale is our expertise, which others cannot just copy. Also we do not merely repeat what they have given us, we improve the process by using our knowledge and make it more viable - so secrecy is not entirely lost by giving out the project."

Project Contract and Implementation Structure: The firm contracts upstream research to a TI which has greater expertise and experience in work of that nature, and can execute it faster and more economically. The TI implements the project independently and if the upstream research is successful, the firm takes a technology transfer of the research output. The firm then works independently on downstream R&D up to the commercialisation of the product or process.

For example in the SUN project it was agreed between SUN and IICT that IICT would independently develop the drug to the laboratory scale of production and then transfer the process to SUN which will then do subsequent work for commercialisation of the product. The latter required work at SUN on scaleup to pilot plant and production scale, as well as work on aspects related to quality and commercial viability of the production process. This sequential division of work was stated in the memorandum of understanding signed with IICT.

Feasibility and Viability of the Project Implementation Structure: This project implementation structure is feasible if the project technology allows for a clearly independent and temporally sequential division of work between the TI and the firm. Since the firm contracts out the upstream research part of several projects completely to a TI, it is essential that the project technology and nature of work be such that the upstream research and downstream R&D parts are clearly independent and can be sequentially divided between the TI and the firm. The upstream research output should be easily transferable from TI to firm in a one time intensive interaction so that the firm can independently work on downstream R&D. This also means that the tacit component in the technology to be transferred should be low. Compared to the firm, it is essential for the TI to have clearly superior expertise, capability and cost advantage in doing upstream research. Also, compared to the TI, it is essential that the firm should have clearly superior expertise, capability and cost advantage in doing downstream R&D.

This is shown by a statement of an FDC project leader: "These large institutes (TIs) have the back up of costly analytical instruments which we cannot afford. They have the expertise and resources to shorten the R&D cycle time. Their specialised equipment, instrumentation for basic work and specialised knowledge can cut development time. We cannot have or acquire these equipment as it is not economically viable for us. From these six projects, even if one or two click it is worth it. It gives us substantial shortening of cycle time in product development."

<u>Motivations of the Firm</u>: The firm's primary motivation is rapid technology sourcing at low cost, to expand its portfolio of projects in order to reduce risk, and have sufficient successful projects to maintain markets share and competitive position, in a market characterised by high new product activity. Alternatively the firm, facing high competitive pressure, wants to get results as rapidly as possible, and therefore cannot spare the time to experiment and learn on its own while doing upstream research for all the projects.

R&D in the pharmaceutical industry in very expensive and results are highly uncertain. Drugs are usually very expensive at the time of introduction. The firm which introduces the drug has to enter as early as possible even if the manufacturing route is very expensive, and then work at improving efficiency and reducing the price by using cheaper substitutes and alternate routes. The cost then drops and the firm *also drops the price around the time its competitors introduce the drug. Once several competitors enter, the price drops very rapidly to a fraction of the introduction price. Though the risk in each project individually was high, the firm's investment relied on the estimate that atleast a few of their projects were likely to be successes and the high return from these successes would more than adequately cover the losses from the failures.*

Constraints of the Firm: The firm identifies several projects with clearly definable end results which are to be implemented. The new products or processes to be developed are in a familiar technology area, but the firm either does not have adequate resources (manpower and/or equipment), or cannot spare the resources required for implementing the upstream research part of all the projects in a large project portfolio - it can do only a few of them. The firm may be also be relatively slower at upstream research and may find the large investments required, difficult to make.

SUN needed to work faster on its product development to match market requirements and it could not devote its scientists for upstream research which could require an initial period of two or three years.

Firm's Choice of TI: Having chosen to implement projects jointly with TIs, the firm has to choose the appropriate TI for each project. The firm keeps track of the quality of work and areas of interest of the relevant TIs and their scientists through their publications, presentations at conferences, and news items in the general and industry specific media. Past employees of TIs working in the firm also keep in touch with their earlier colleague network. The firm therefore has a fair idea regarding which TIs to approach for each of their projects. The firm's choice of TI is based on the reputation and confidentiality of the scientist, his/her credibility in finishing the project on time and availability of adequate facilities at the TI.

The choice process is described by an FDC project leader: "We have been in bulk drugs for 18 years. We have seen and interacted with these institute professors and students. Their publications are familiar to us. We attend their lectures and meet them in conferences. So we get to understand them better. We know the areas of expertise of these institutes, the work they have done and the expertise level of the professors. We approach them informally and talk to them about potential projects. We have a dialogue and gauge their interests. Then we informally propose the project. If they are *interested then we go ahead."*

TI's Considerations: When approached by the firm, the TI accepts the project if it broadly falls within its current or future areas of research, and if it can contribute to its knowledge and experience. The TI sees such projects as a means to keep in touch with the industry, apply its knowledge, earn revenue, train students or junior scientists and advance work in their own area. The TI may have the required expensive equipment that the firm lacks, or finds unviable to purchase, or which is not available elsewhere. In such cases, considering their charter, the TI may be obliged to accept the project. The TI faces time constraints due to its teaching workload and other concurrent projects. The project is in a technology area which is familiar to the TI and the TI has typically handled similar projects in the past. Though there is uncertainty, earlier experience with similar projects leads the TI to make reasonably accurate estimates of the time and resources required to implement the project. The project is essentially of commercial importance to the TI and one of a stream of projects for the TI. Any particular project is not of great individual importance but to have sufficient projects is however very important for the TI.

For example at IICT, in general contract projects from the industry are sought after as they represent opportunities for utilising the TIs expertise in solving real industrial problems, for generating revenue for the TI and to help in the development of their internal research agenda. When a project is proposed to IICT, it checks on: (a) the feasibility of implementing it at their premises and (b) whether it is in an area of interest for them. IICT usually takes up any project in the pharmaceutical area. IICT does not take projects in areas where they do not have the specialised equipment or manpower. In such cases, they recommend other institutes which they know have these capabilities.

Familiarity of TI with Technology Area: The technology area required for implementing the project is familiar to the TI and it has done upstream research for similar projects in the past. This earlier experience is useful for, though not directly applicable to the proposed project.

For example in the SUN projects, though each project was independent of others, the nature of upstream and downstream research required was similar across the projects. Experience gained by the firm and TI in earlier projects was useful in *decreasing the developmental period and the experimentation required before reaching the final solution.*

Technological Nature of the Project: The projects do not usually represent major breakthroughs in technology, but involve incremental and often repetitive experimental refinement of known technology. However, they are not just applications of known technology; their end results are patentable new products or processes.

For example in the SUN case, the work at IICT required a large number of experiments to put the process route into practice in local conditions, to refine the process and standardize it. Subsequent work at SUN involved engineering design and experimentation for scaleup. They also had to examine the legal and market requirements regarding impurity profiles, toxicity levels etc. and make suitable changes in the process. Changes were also required to adjust to available raw materials and for economising on production cost.

Project Implementation and Learning Process

The project implementation and learning process in such contract projects is described in this section and illustrated through the FDC and SUN case examples. In this project implementation process, the project moves from upstream research work at the TI, to TI-firm technology transfer, to downstream R&D at the firm. At the onset, the project work is clearly and sequentially divided between the firm and the TI. The TI exclusively does the basic product or process development at the laboratory scale till technical feasibility is reached - *"TI Phase"*. The TI then transfers the technology to the firm - *"Transfer Phase"*. The firm then exclusively works on developing the product or process for commercial production, including making changes required to make the it more viable - *"Firm Phase"*. There is a clear separation of the TI and firm work phases, with a clearly differentiable technology transfer phase in between. The phases are described below:

TI Phase: The upstream research part of the project is implemented independently and entirely by the TI. At the TI, this "TI phase" of the project is characterised by development and experimentation at the laboratory scale. As the projects involve incremental and repetitive experimental refinement of known technology rather than entirely new technology development, the task is usually given to students or junior scientists, for whom the work has more experiential value. During the project work at the TI, the firm supports the TI in accessing inputs from outside sources, which the TI may find difficult to procure speedily. During this period, the TI only report results periodically to the firm and rarely interacts with it. The firm is only involved in keeping tract of the TIs work through such reports.

Interaction during the TI Phase: Once the firm has communicated its expectations, TI-firm interaction during the "TI phase" is low. The frequency of communication is low as it usually unnecessary or irrelevant and is usually limited to reports about success or failure at each technical stage of the project. Interaction is even lower when the firm and TI are in different cities. Given low communication and no interaction between the two, there is no gain in practical experience and no new knowledge gain for the firm during this phase.

This is shown in the SUN & FDC cases. Both SUN and FDC situated at a distance of about 1200 and 1000 kilometres respectively from IICT. In the SUN projects the project leaders at IICT only had telephonic contact with SUN, till they came for the demonstration at the end of the IICT phase of the project. However, they received letters and status reports sent by IICT. The reporting frequency depended on the project process - on the "product chemistry." Initially for six months no report was required as IICT carried out the background work including the literature survey. After that the frequency increased to once a month and later when IICT was about to complete the reporting was very frequent (weekly). Said a project leader at FDC - "It is difficult to keep track of what is happening at IICT. We cannot often go to IICT as it is expensive. But we communicate by telephone or courier or fax. With outside institutes it is difficult to interact. The institute must be near or communication gap always remains."

Transfer Phase: Once the TI successfully completes the upstream research part of the project, it invites the firm's project team over for a demonstration of their developed product or process. The firm sends a set of people to the TI for a short period, for technology transfer. These people are selected from among those who will work further on the downstream research part of the project, for making the developed product or process suitable for viable commercial production. They are knowledgeable enough to absorb the technology rapidly and make all possible enquiries required for subsequent work at the firm. During the short period of intensive interaction at the TI there are demonstrations of the upstream research output by the TI. The firm's project team also take repeat trials if required to check the repeatability of the process and to ensure that they understand it and can repeat it at their own laboratory.

This process is described in the SUN & FDC cases as follows: "They finished their work and then informed us that the process is working and ready. Then we went there for two to three weeks to get to know how to do the process. They first demonstrate it then we do it in front of them. Then we come here and repeat it here at our laboratory." said a scientist at SUN. "They want to transfer the technology as fast as possible. Also the students working on the project want to finish it fast so that they can graduate. Once one or two production batches are taken we are usually satisfied that we have a good understanding of the process. We usually send an experienced group that can grasp the technology and return at the earliest." - said a scientist at FDC.

Interaction in the Transfer Phase: In the transfer phase of the project, intensive interaction takes place between the TI and firm project teams. There is keen questioning by the firm on avenues explored and unexplored by the TI. This is useful for the downstream R&D work later at the firm. The firm's project team asks several questions to learn about the technical development process followed by the TI specially about avenues already explored by the TI so that they are not repeated by the firm.

For example in the SUN case, during the interaction at IICT for the basic process demonstration, SUN scientists also questioned the IICT scientists and technicians about the experimental route that they had used - specially about the alternatives they had tried which had failed. This was important information for them so that they did not repeat failed routes during the scale up work at SUN.

Firm Phase: Once the upstream research part of the product or process has been understood and successfully tried by the firm's project participants at the TI laboratory, they go back to their own laboratories to work independently on downstream R&D for converting it for viable commercial production. In this "firm phase" of the project, the work involves making changes in raw material and refinement of process parameters to suit resource constraints, available materials and customer requirements. The end product or process may therefore be substantially different from the one given by the TI. This also allows the firm to maintain secrecy of the technology till it is patented and launched.

For example a scientist from SUN said - "We work only after their (IICT's) work is over. We come here and repeat the process and try suitable modifications. They only show how it works; just the "chemistry outline". We have to work on many factors such as (a) yield - the quantum of yield? (b) the reagent - is it necessary? (c) can we replace solvents? (d) can we shorten the reaction time? (e) can we change reagents?"

Interaction in the Firm Phase: During the "firm phase" of the project there is no activity at the TI except to answer rare queries from the firm which were not covered during the technology transfer phase. Apart from clarificatory communication there is no interaction between firm and TI in this phase.

For example in the SUN case, once they received the basic process, SUN enhanced the scale according to their needs and worked independently. They did not seek any help from the IICT except for clarifications on the basic processes.

Learning during the TI Phase: In the "TI phase", learning is entirely within the TI, embodied in the experience gained by the students or junior scientists and their project head. This experience may have utility in their further research programme in the same or similar areas. Little or no technology transfer takes place from TI to firm during this phase. Learning within the TI is also through high interaction within the project group. They learn to apply knowledge to practice and gain in practical experience. For the senior scientist or project head who guides them, learning is primarily of the "what worked and what did not work - and why?" nature, derived from the large number of experiments conducted by the project team.

For example at IICT the learning was in developing new processes through experimentation and trial and error. While this did involve some repetitive type of work, it also provided useful practical experience to the students/chemists conducting them. Learning also related to why some process routes worked while others did not. Such experience was found useful by them for subsequent projects.

Learning in the Transfer Phase: The learning during the transfer phase is through demonstration. The firm learns by watching, doing and questioning as it taps on the TI's experience. The scope and quantum of technology transfer during this interaction is largely dependent on the ability of the firm's personnel to ask relevant questions, and absorb knowledge within a short period. However, there is limited transfer of experience and tacit knowledge, as the interaction is for a very short period.

In the words of a scientist at SUN - "They (at IICT) will only demonstrate their work. The learning depends on the interaction between our chemist and theirs. We can ask them about alternative routes and reagents. If they have not tried some route or reagent then we can try it here at the SUN research centre. If they have tried a route and failed then we need not try the route again. We ask about why they chose certain reagents so that we can make replacements if required with alternatives that are more economical and available. We prepare our questions about all the choices and ask them when we go there."

Learning in the Firm Phase: During the firm phase, the firm gains practical experience in downstream R&D required for converting the basic upstream product/process to viable commercial production. This experience is useful for similar future projects. This knowledge is however retained by the firm and not actively sought by the TI scientists. The learning at the firm is through high interaction within the project group. They learn to apply knowledge to practice and gain in practical experience and practical knowledge.

Interest and Relationship: Such projects are characterised by a medium level of personal and organisational interest in the project at both the firm and the TI. Both organisation's CEOs provide only administrative support, while the next level takes the initiation and co-ordination roles. The TI-firm relationship is primarily contractual. The initially decided contractual agreement is strictly followed by both parties. This is facilitated as the project is clearly defined at the beginning. Any deviations required are renegotiated.

Problems and their Resolution: Problems in the project process are usually related to delays in project implementation. As they are seen as one time problems rather that generic issues to be resolved, they are usually coped with rather than solved. The physical distance between firm and TI and the low communication during the project also make it difficult for such problems to be resolved.

Evaluations and Consequences of the Project

This section covers the parameters on which the firm and the TI evaluate each other after the project is completed. It also covers their vision of the consequences of the project for future interaction between the two organizations. These are synthesized from the cases of pharmaceutical firms developed in this research.

Evaluation of the TI by the Firm: On completion of the project, evaluation of the TI by the firm is based on their perception of the TI project team's knowledge base, their ability to keep the project technology confidential, the speed of implementation of the project and against project success parameters and the success rate in multiple projects. It is also based on whether the criteria used for selecting the TI initially held true during the project. Success in the project, or success rates in the case of multiple projects by the TI, are evaluation criteria, as these have important viability implications. The firm is positive about giving the TI future contracts, if these expectations are met.

Evaluation of the Firm by the TI: Similarly, on completion of the project, evaluation of the firm by the TI is based on their project team's clarity in communicating their requirements and expectations, timely and appropriate support in accessing inputs from outside sources, and ease of technology transfer due to adequate knowledge base among the firm's personnel. The TI is positive about accepting future contracts from the firm, if these expectations are met.

Expected Consequences: If evaluations by both TI and firm regarding each other are positive then similar new projects are expected by the TI and given by the firm in future.

Tables 1 and 2 about here

Discussion And Conclusions

This paper contributes a mapping of the process through which firms initiate and implement a portfolio of contracts for upstream research with TIs in an attempt to get rapid results with reduced costs and risks, while concentrating their limited R&D

resources on downstream research. As shown, this strategy can be a viable technology acquisition option for firms, under certain initial and process conditions. Firms and TIs can examine the process model and description to draw lessons on creating appropriate ground conditions which facilitate the initiation of such collaborative projects, and therefore gain the risk reduction benefits available from this strategy.

This research complements the more common large sample survey based studies of TI-firm research collaborations which, while providing an overview of the firm and TI motivations and explaining the existence or nonexistence of such collaborations, are not designed to describe the initiation and implementation *process*, which is key to developing policy mechanisms that initiate and facilitate such projects. Directions for future research are: (a) testing for the accuracy and completeness of the developed process model and its identified stages and sub-processes, (b) comparison of the model with models of joint activity between organisations of various types, (c) developing scales and operationalizing the various components of the model.

While providing empirically grounded theory development in this field, this research can also enable practitioners and policy makers in first, understanding effective processes for initiating and implementing such collaborative projects for mutual benefit, and second, modifying structural conditions to initiate an effective implementation process in them. The process model is useful in understanding how factors at the individual, organizational and inter-organizational level combine to initiate and implement such research collaborations. It can also provide insights aiding understanding and decision making by firms, TIs and policy makers in facilitating and strengthening TI-firm interaction, and in initiating, executing and sustaining a progressive programme of such projects.

References

[1] Technology institutions for the purpose of this research are independent, autonomous not-for-profit institutions involved in technological R&D including government laboratories, technological universities, technology education institutes, industry association laboratories and research foundations.

[2] S. Lee, Z. Bae and J. Lee. 'Strategies for Linking Vertical Co-operative R&D to Commercialisation in Korea', Journal of Product Innovation Management, 11, 1994, p.325-335

[3] M. Dodgson, Technological Collaboration in Industry: Strategy Policy and Internationalisationin Innovation (London, Routledge, 1993).

[4] N. Rosenberg & R. R. Nelson, 'American Universities and Technical Advance in Industry', Research Policy, 23, 1994, p. 323-348.

[5] A. Bonaccorsi & A. Piccaluga, 'A Theoretical Framework for the Evaluation of University-Industry Relations', R&D Management, 24, 1994, p. 229-247.

[6] A. J. Bailetti & J. R. Callahan, 'The Co-ordination Structure of International Collaborative Technology Arrangements,' R&D Management, 23, 1993, p. 129-146.

[7] D. J. Bower, 'New Technology Supply Networks in the Global Pharmaceutical Industry', International Business Review, 2, 1993, p. 83-95.

[8] E. Wittaker & D. J. Bower. 'A Shift to External Alliances for Product Development in the Pharmaceutical Industry', R&D Management, 24, 1994, p.249-260.

[9] B. Bird, D. T. Hayward & D. N. Allen, 'Conflicts in the Commercialisation of Knowledge: Perspectives from Science and Entrepreneurship', Entrepreneurship Theory and Practice, 17, Summer, 1993, p. 57-77.

[10] Bonaccorsi & Piccaluga, *op. cit.*, Ref. 5.

[11] Bower, *op. cit.*, Ref. 7

[12] E. M. Berman. 'The Economic Impact of Industry Funded University R&D', Research Policy, 19, 1990, p.349-355.

[13] R. E. Lopez-Martinez, E. Medellin, A. P. Scanlon & J. L. Solleiro, 'Motivations and Obstacles to University - Industry Co-operation (UIC): A Mexican Case', R&D Management, 24, 1994, p. 17-31.

[14] Rosenberg & Nelson, *op. cit.*, Ref. 4.

[15] Bailetti & Callahan, *op. cit.*, Ref. 6.

[16] C. Alter & J. Hage, Organisations Working Together (Newbury Park, California, Sage, 1993) p. 98.

[17] B. Glaser & A. Strauss, The Discovery of Grounded Theory: Strategies for

Qualitative Research (London, Wiedenfeld & Nicholson, 1967).

[18] R. K. Yin, Case Study Research: Design and Methods (Beverly Hills, California, Sage, 1984).

[19] H. Tsoukas, 'The Validity of Idiographic Research Explanations', Academy of Management Review, 14, 1989, p. 551-561.

[20] A. Parkhe, 'Messy Research, Methodological Predispositions and Theory Development in International Joint Ventures,' Academy of Management Review, 18, 1993, p. 227-268.

[21] R. A. Burgelman, 'A Process Model of Internal Corporate Venturing in the Diversified Major Firm', Administrative Science Quarterly, 28, 1983, p. 223-244.

[22] Yin, *op. cit.,* Ref. 18.

[23] K. M. Eisenhardt, 'Building Theories from Case Study Research', Academy of Management Review, 14, 1989, p. 532-550.

[24] Yin, *op. cit.,* Ref. 18.

[25] B. S. Chakravarthy & Y. Doz, 'Strategy Process Research: Focusing on Corporate Self Renewal', Strategic Management Journal, Summer Special Issue, 13, 1992, p. 5-14. (p.8).

[26] Parkhe, *op. cit.,* Ref. 20.

[27] Eisenhardt, *op. cit.,* Ref. 23.

[28] Yin, *op. cit.,* Ref. 18.

[29] Eisenhardt, *op. cit.,* Ref. 23.

[30] M. B. Miles & M. A. Huberman, Qualitative Data Analysis (Beverly Hills, California, Sage, 1984).

[31] Yin, *op. cit.,* Ref. 18

[32] Eisenhardt, *op. cit.,* Ref. 23

[33] commercial importance - able to generate revenue and maintain market position, but not closely linked to the strategy of the firm - no single project in the project portfolio is of overriding importance.

[34] strategic importance - linked to the strategy of the firm and used as a medium for achieving the strategy.

Table 1. Antecedent conditions and joint project initiation process

Project Features	Vertical Collaborative TI - Firm R&D Project
Importance level for firm	Commercial importance; firm needs to expand project portfolio to have sufficient new projects and reduce its overall project risk
Firm's familiarity with technology area	Technology area familiar to firm
Need for firm to outsource technology	Firm lacks adequate manpower and/or equipment
Firm's major motivations and benefits	Rapid low cost technology sourcing, to reduce risk and have sufficient new products to maintain market presence
Firm's major constraints	Lacks adequate resources for upstream research in all projects of a large project portfolio or cannot spare the required resources
Firm's choice of TI primarily based on	Adequacy of the TI's facilities, confidentiality and reputation of concerned scientist, credibility in finishing project in time
Importance level for TI	Project of commercial importance to the TI and one of a stream of such projects for the TI
TI's familiarity with technology area	Technology area familiar to TI
TI's considerations	To keep in touch with industry, apply knowledge, earn revenue, train students or junior scientists, advance work in their area
TI's criteria	Project should fall within areas of research and experience base, time constraint due to teaching workload and other projects
Project process mode is feasible if	There is clearly, independent sequentially dividable work for the firm and the TI, the TI's output is easily transferable to the firm, there is low tacitness of knowledge to be transferred
Project process mode is viable if	In its part of the project each has clearly superior expertise, capability and cost advantage compared to the other
Project structure	Upstream research is contracted to the TI, the TI implements it independently, if the research is successful then firm takes a technology transfer, firm then works independently on downstream R&D till commercialisation of the product/process

Table 2. Project process, learning and evaluation

Project Features	Vertical Collaborative TI - Firm R&D Project
Project process	Upstream research work at TI followed by TI to firm technology transfer followed by downstream research work at firm
Initial activity at TI	Upstream research, experimentation and refinement of technology
Initial activity together	Low communication, no interaction, no joint activity
Initial activity at firm	Keeping track of TI work through reports
Technology transfer activity	Short period of intensive interaction at TI, demonstrations by TI and repetitions by the firm
Later activity at TI	To answer queries from firm that were not covered in the technology transfer phase
Later activity together	Only clarificatory communication, no interaction, no joint activity
Later activity at firm	Downstream R&D, work required for making changes to suit market requirements and resource constraints
Problems and their resolution	Related to delays in project implementation, seen as one time problems, coped with rather than solved
Learning at TI	Through high interaction within project group, learning to apply knowledge to practice, gain in practical experience and practical knowledge
Learning during technology transfer	Through demonstration, firm learns by watching, doing and questioning, tapping on TI's experience, limited transfer of experience and no tacit knowledge transfer
Learning at firm	Through high interaction within project group, learning to apply knowledge to practice, gain in practical experience and practical knowledge
Evaluation of TI by firm based on	TI's knowledge base, maintaining confidentiality, speed of implementation, against project success parameters and success rate in multiple projects
Evaluation of firm by TI based on	Clarity in communicating requirements, timely input sourcing support, ease of technology transfer, adequate knowledge for ease in technology transfer

Figure 1 **Process Diagram of Vertical Collaborative TI-Firm R&D Project**

Project Structure	Mode is Feasible if there is	Mode is Viable if
upstream research contracted to TI, TI implements it independently, if successful, the firm takes a technology transfer, firm then works independently on downstream R&D till commercialisation	clearly, independent sequentially dividable work, upstream research output easily transferable to firm, low tacitness of knowledge required to be transferred	in its part of the project each has clearly superior expertise and capability compared to the other and clear cost advantage over the other

Project Initiation Phase

R&D Project of Commercial Importance to the Firm

Firm's Motivations/Benefits
rapid technology sourcing, low cost sourcing, expand project portfolio to reduce risk and have sufficient new products to maintain markets

Firm's Constraints
lacks adequate resources for upstream research in all projects in a large project portfolio or cannot spare resources

Technology Area Familiar to Firm

↓

Firm's Choice of TI
is based on the confidentiality of scientist, reputation of scientist, credibility in finishing project in time, adequate facilities at the TI

↑

Positive evaluation of TI by firm based on earlier interaction if any

→

R&D Project of Commercial Importance to the TI

TI's Expectations
keep in touch with industry, apply knowledge, earn revenue, train students or junior scientists, advance work in their own area

TI's Criteria
project should fall within areas of research and experience base, time constraint due to teaching workload and other projects

Technology Area Familiar to TI

↓

Project Accepted by TI
based on its ability and availability of resources to handle project, project selection criteria, norms of TI, assessment of firm's interest in project

↑

Positive evaluation of firm by TI based on earlier interaction if any

next page →

Figure 1 (cont.) **Process Diagram of Vertical Collaborative TI-Firm R&D Project**

Project Implementation and Outcomes

Project Process: Work at TI →TI to Firm Technology Transfer → Work at Firm

At TI →	**"TI Phase"** experimentation and refinement of technology, gain in experience, practical knowledge gain →	**"Technology Transfer Phase"** initiated once basic R&D is successful in the "TI Phase", TI invites firm over, short period of intensive interaction at TI, demonstration by TI and repetition by firm, keen questioning by firm on avenues explored and unexplored by TI for use in downstream R&D work at the firm →	**"FIRM Phase"** no activity except to answer queries from firm which were not covered in the technology transfer phase →	**Learning at TI** high interaction within project group, learning to apply knowledge to practice, gain in practical experience and practical knowledge
At Inter -face →	↑ *low communication no interaction* ↓ →		↑ *clarificatory communication no interaction* ↓ →	**Learning during Technology Transfer** through demonstration, firm learning by watching, doing and questioning, tapping on TI experience, limited transfer of experience and no tacit knowledge transfer
At Firm →	**"TI Phase"** keeping track of TI work through reports, no gain in experience, no knowledge gain →		**"FIRM Phase"** downstream R&D, refinement, changes to suit market requirements and resource constraints, scale up for commercial production →	**Learning at Firm** high interaction within project group, learning to apply knowledge to practice, gain in practical experience and practical knowledge

Problems and their Resolution: problems related to delays in project implementation, seen as one time problems, coped with rather than solved