A PROCESS TYPOLOGY OF UNIVERSITY-INDUSTRY JOINT PRODUCT DEVELOPMENT PROJECTS*

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A Process Typology of University-Industry Joint Product Development Projects*

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Abstract

I propose a process typology of joint product development projects that are initiated by industrial firms and implemented jointly with technological universities or not-for-profit research institutions. The four ideal types of university-industry joint product development projects proposed in this typology were synthesising from in-depth case studies of twelve projects implemented jointly by six firms with seven technology universities or institutions. This paper contributes to research on joint product development by proposing an empirically grounded process typology based on combinations of initial contextual and technical knowledge possessed by the firm and the university. Each ideal type represents a synergistic combination of initial conditions and project implementation process that lead to successful project completion (insurmountable technical difficulties apart). The paper maps the web of inter-linked project processes in each ideal type and indicates their anticipated impacts on firm and university activities. It also provides a comparative analysis of the essential linkage of antecedent conditions and motivations for the initiation of the joint project, to the actual project implementation process in which the two collaborators contribute complementary resources, and further to the project's expected consequences, for each ideal type in the process typology. The typology frame, the comparison tables and the accompanying descriptions show the internal consistency within each ideal type and the contrasts across the ideal types. Given initial conditions, the ideal type descriptions can be tentatively used as templates by firms and universities for predicting and guiding the course of their joint product development projects.

Key words: process, typology, product development, university

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A Process Typology of University-Industry Joint Product Development Projects

1. Introduction

Industrial firms that realise that they lack the technical knowledge and resources to develop certain products on their own, can develop them by tapping on the complementary knowledge and resources of technological universities through joint product development projects (Bonaccorsi and Piccaluga, 1994). According to Bailetti and Callahan (1993), some factors which drive technology based firms to use collaboration for product innovation are: (a) significant technological discontinuities, (b) the convergence of technology and markets, (c) the rise of technological standards which significantly affect product markets, and (d) the scale increases required in research and development for global markets. However studies of technological university - industrial firm collaborations for product development have largely concentrated on identifying the antecedent conditions for initiating collaboration and on identifying their perceived or actual consequences, rather than on their important *implementation process*. Therefore there is need for a clear process based linkage between the identified antecedent conditions of the product development project, the process of managing the university-firm joint product development project, and its identified consequences.

This paper provides an empirically derived process typology and comparative analysis of the process of initiation and implementation of four ideal types of technological university - industrial firm joint product development projects. Technological universities for the purpose of this research are independent, autonomous not-for-profit technological institutions involved in technological research and development (R&D) including government laboratories, universities, education institutions, industry association laboratories and research foundations. The process typology and comparative analysis contributes significantly to literature on university-firm joint product development by depicting the essential linkage of antecedent conditions and motivations for the joint project initiation, to the actual project implementation process in which the two collaborators contribute complementary knowledge and resources to the joint project, and further to their expected consequences in each ideal type of project. It maps the web of inter-linked project processes in each type of project and indicates their anticipated impacts on firm and university activities. It also shows how knowledge is jointly created and transferred in the each type of project. The process typology has been developed by synthesising in-depth case studies of several university-firm joint product development projects. Each ideal type represents a synergistic combination (Doty and Glick, 1994) of initial conditions and project implementation process that led to successful completion (insurmountable technical difficulties apart). Given initial conditions, the ideal types can be tentatively used as "templates" by firms and universities for predicting and guiding the future course of their joint product development projects.

2. Methodology

Given inadequate process research on university-firm joint product development projects, it was considered necessary to conduct a process study, using qualitative research methodology, to gather process data for developing the process typology (Doty and Glick, 1994). Grounded (Glaser and Strauss, 1967) case research is considered an appropriate (Alter and Hage, 1993; Parkhe, 1993; Ring and Van de Ven, 1994; Zajac and Olsen, 1993) and valid (Tsoukas, 1989) approach for studying inter-organisational process issues. The longitudinal processual method of case research (Burgelman, 1983) was adopted to develop multiple qualitative process case studies with the university-firm joint product development project as the unit of analysis. Multiple cases provide greater scope for attempting analytical generalisation (Yin, 1984) compared to a single case and provide an understanding of the complexity and richness of the project initiation and implementation process, considering the paucity of previous process research. The broad research approach adopted was in the holistic tradition (Chakravarthy and Doz, 1992: 8) 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.'

Twelve projects implemented jointly by six firms with seven universities were selected from a list of over eighty university-firm joint product development projects that was made available by a development financial institution (DFI) that funds and facilitates such projects under a special technology development financing scheme. A variety of projects were selected to enable replication and comparison, thus building external validity (Eisenhardt, 1989) and expanding the domain of generalisation (Yin, 1984). The data collection was primarily through in-depth semi-structured and open-ended personal interviews of about an hour to two and half-hours with forty key project participants in multiple hierarchical levels and departments in both organisations as well as the DFI. The open-ended questions allowed respondents to give descriptive answers and to elaborate wherever necessary. The interviews traced the project process from inception to completion and also covered background information on the organisation, industry, and environment. To gather as much as possible the richness of the project process, new topics that emerged during the interviews were explored, and new questions were added for subsequent interviews (Eisenhardt, 1989). All interviews were completely transcribed (167 pages) and supplemented by personal observations, written communications, records and reports (Yin, 1984).

This research was set in Eisenhardt's (1989) framework for building theory using case study research. 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. While working through the multiple projects, themes and issues gradually reoccurred and over the set of projects there were repetition of process details indicating that theoretical saturation (Eisenhardt, 1989) had been reached. When sufficient repetitions occurred to ensure external validity (Eisenhardt, 1989) no further projects were studied. The Miles and Huberman (1984) 'categorisation and theme analysis' technique was then used to develop cases from the interview and background data. Draft cases were read, corrected and cleared by the concerned firm in consultation with the collaborating university. While structuring the written cases, the focus was on the development of causal patterns over time within cases and on the development of general patterns across cases. This analysis served as inputs for the inductive development of the process typology and comparative analysis. As this research was of an exploratory nature, I stopped after using the empirical base to identify the project process and to inductively develop the process typology. Further research is required for testing the adequacy of the variables included in the comparative analysis and the completeness and accuracy of the proposed process typology.

3. Process typology

A typology frame containing four ideal types (Doty and Glick, 1994) of university-firm joint product development projects based on combinations of initial contextual and technical knowledge possessed by the firm and the university, was developed through induction from the empirical data (Eisenhardt, 1989). This typology frame is presented in Figure 1 along with short ideal type descriptions of initial conditions, implementation process and outcomes of the four ideal types. Of these only the first three ideal types were empirically derived from the case research. These are: (a) "ideal type one" descriptively labelled as *Contract Technology Development*, (b) "ideal type two" descriptively labelled as *Interactive Technology Transfer* and (c) "ideal type three" descriptively labelled as *Joint Technology Development*. "Ideal type four" was inductively derived from the typology frame (Doty and Glick, 1994) and was not found in the empirical research. Future work can empirically identify this ideal type, though it is predicted through the typology frame that its process could mirror that of ideal type two *Interactive Technology Transfer* with the university and firm roles interchanged.

Figure 1 about here

In a *Contract Technology Development* (CTD) type of joint product development project, even though the firm has the required technical capability, it contracts out the upstream (laboratory scale) research to a university that implements it independently. If the university succeeds in developing the basic laboratory scale process, the firm takes a technology transfer of the basic process in a short one time intensive interaction. The firm subsequently works independently on the downstream (commercial scale up) research component of the project. An example of a firm involved in joint product development projects that closely matches the CTD ideal type is Sun Pharmaceutical Industries Limited, a small pharmaceutical firm based in Baroda, India. The firm sub-contracted the Indian Institute of Chemical Technology at Hyderabad, India, a not-for-profit government pharmaceutical and chemical technology institution (deemed university), to develop the basic laboratory level process for five bulk drugs The university applied its technical knowledge to the firm's basic process development requirement The firm then took a technology transfer of the laboratory level process for each of the bulk drugs from the university and then worked independently in applying its technical knowledge on the commercial scale up of the process in its own research centre at Baroda, India.

The *Interactive Technology Transfer* (ITT) type of joint product development project involves the use of some skills, technology and equipment that are not available with the firm in-house but are available with a local university. The firm needs to acquire these skills, technology and equipment; both for the immediate project and for future work in that technology area. The firm finds it viable to contract the university for assistance in jointly implementing the immediate product development project that requires the new technology, while simultaneously training it and helping it acquire the new technical knowledge and equipment, through regular intensive interaction during the project. An example of a joint product development project that closely matches the ITT ideal type is one between Guindy Machine Tools Limited, a small machine tool manufacturing firm based in the Indian city of Chennai (formerly Madras) and the Indian Institute of Technology, a not-for-profit government technological institution (deemed university) also based at Chennai, India The project involved jointly designing and developing a sophisticated machine tool, primarily for export to the developed countries, using a design technology that was new to the firm (as well as the Indian machine tool industry in general), but was familiar to the university professors The university applied its technical knowledge to the firm's contextual product development requirement with the firm providing the contextual knowledge The firm learnt the new design technology from the university for future application, while implementing the joint product development project

The *Joint Technology Development* (JTD) type of joint product development project involves the development of a product or process along with the creation of new technology, or significant leap from present technology It requires the use of complementary knowledge, skills and equipment available with both the university and the firm The firm contracts the university for jointly developing new technology by pooling their complementary capabilities and resources An example of a joint product development project that closely matches the JTD ideal type is one between Electronica Mechatronic Systems (India) Private Limited, an electronics firm based in Pune city, India with the Centre for Devèlopment of Advanced Computing, a government supported not-for-profit supercomputing technology development institution also based in Pune, India. The project involved the development of an advanced computer chip based digital readout device for use on computer numerical control machine tools. This product development project required a significant leap from the state-of-art technology at that time and required the use of complementary contextual knowledge, skills and equipment available with both the institution and the firm.

4. Comparative analysis

A comparative analysis of the differences between the three empirically derived ideal types (CTD, ITT and JTD) of university-firm joint product development projects, is presented in this section. This comparative analysis covers the antecedent conditions of the project, motivations and constraints for the firm and university, the DFI's project selection and role, the project process, its outcomes and post project mutual evaluation by the firm and university. The comparison highlights the logic and internal consistency within each of the three ideal types and the differences across the ideal types (Doty and Glick, 1994). The accompanying tables are useful in showing the contrasts between the ideal types.

Table 1 about here

4.1 Firm related factors

A comparative analysis of the antecedent conditions, motivations and constraints faced by the firm in the three ideal types of university-firm joint product development projects is presented in Table 1. In the CTD type each joint product development project is part of a portfolio of high-risk new projects being undertaken by the firm. The firm is interested in expanding its portfolio of projects, so that it can reduce the risk of its project portfolio and have sufficient projects to stay in the market dominated by new product activity. To do so it needs a large R&D resource base, which is unviable for it to maintain in-house. The firm in the

CTD type therefore leverages its limited but technically capable R&D resources by contracting out the basic research part of the project to universities and taking technology transfer of successful projects for in-house development from laboratory (basic research) stage to production (applied R&D) stage. In doing so it is able to maintain secrecy and apply proprietary in-house skills for applied R&D to develop a viable product or process. The firm contracts out part of the project to the university in an area where the firm itself has familiarity with the technology area and can handle basic research but believes that the university can do it faster and cheaper. It chooses the university (and its scientist), after a careful search, on the basis of the adequacy of the university's facilities, the confidentiality (to maintain secrecy) and reputation of the scientist, and his/her creditability in finishing projects within the promised time.

In contrast to the CTD type, the ITT project is usually the only one, or one of the few joint product development projects being implemented by the firm and the project individually holds great importance for the firm both for itself and for its potential to contribute to the technological resource base of the firm. The joint product development project is of strategic importance to the firm in the sense that it is linked to the firm achieving its strategic goals. Apart from developing the product itself, the firm needs to learn the technology required for it, to meet immediate and future needs. As the project is in a technology area which is unfamiliar to the firm, and which the firm cannot learn on its own, it seeks the help of a university, to both participate and advice it in project implementation and simultaneously teach and train it in the new technology area Apart from lacking the adequate manpower and/or equipment as in the CTD type, the firm in the ITT type also lacks the appropriate knowledge for implementing the project The firm is aware that the university has the technological knowledge and skills to help it in implementing the project The university is usually one with which the firm has had a long and fruitful interaction and has developed a personal and professional rapport Among such universities with which the firm has such a relationship, the firm chooses that university with which it is possible to have regular, close and constant interaction - usually one in its vicinity (same city) (In the CTD type this is not a major issue, the firm searches among appropriate universities anywhere in the country, as close interaction throughout the project is not required) In the ITT type, the firm typically does not go through an elaborate search process and only contacts the local universities working in that technological area

In the JTD type, the project is usually of greater importance for the firm than in the ITT type - apart from being of strategic importance, it is also of critical importance The firm faces a crisis in that the technology it presently uses is already or rapidly becoming obsolete for product development The firm therefore needs new technology but finds no readily usable new technology available, which can be acquired or learnt It is therefore forced to develop new technology for the project, but lacks part of (though not completely as in the ITT type) the knowledge and appropriate manpower and/or equipment required for doing so The new technology required is in a new area for the firm and the firm approaches a university that it believes has the expertise to solve the issue and develop the new technology through a joint product development project The firm approaches a university scientist either on the basis of personal recommendations or earlier personal contact (which has resulted in fruitful earlier interaction and interpersonal rapport) At the time the firm approaches the university, it is not very clear about the exact scope of the project and the quantum of work required for it It hopes that the university will assist it in defining the project scope (This contrasts with the CTD and ITT types, where the project scope is clear at the onset for the firm, and is clearly communicated to the university)

The DFI financing scheme provides risk sharing as well as a low rate of interest The firm in the CTD type approaches the DFI for financing primarily to expand its portfolio of projects by leveraging its investment on the DFI loan and reducing its investment risk In the ITT type, as the project is in a known technology area for the university and the firm has the knowledge that the university has done similar projects in the past, the risk of failure associated with the project is low The firm approaches the DFI, not for its risk underwriting, but because the firm cannot make the large investment required for the project on its own and finds the low interest rate of the DFI attractive In the JTD type, given the lack of definitiveness of the scope of the project and the high risk associated with developing new technology, the firm approaches the DFI for financing primarily for its risk underwriting and because the firm lacks the capacity to make large-high risk investments

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Table 2 about here

4.2 Technology university related factors

A comparative analysis of the antecedent conditions, considerations, motivations and constraints faced by the university in selecting the project, once it is approached by the firm in the three ideal types is presented in Table 2 In the CTD type, the joint product development project is one of a stream of such projects being handled by the university and is selected by it if it fits basic financial and practical criteria The joint product development project is in a technology area that is familiar to the university and the university has typically handled similar projects in the past. Though there is uncertainty and an innovative component in the project, earlier experience with similar projects leads the university to make reasonably accurate estimates of the time and resources required in implementing the project The university sees such joint product development projects as a way of keeping in touch with the industry, as a medium for applying knowledge in the university to practice, to earn revenue for the university and as a medium for training students and junior scientists apart from advancing their work However, the project should fall within the areas of research and experience base of the university, it should have the appropriate infrastructure to implement it, and it should be able to spare the time required for doing so after meeting the requirements of regular teaching and other current projects.

In contrast to the CTD type, in the ITT type, the joint product development project is more than of just commercial importance to the university As the university has typically had a long and fruitful interaction with the firm in the past, it sees this project as one of the series of ongoing interactions with the firm and wishes to continue the interaction that it considers mutually beneficial. The project is in a familiar technology area for the university and it is interested in disseminating the technology to the industry so that the industry can gain practical benefits and the university can see the practical application of the technology (and also gain practical experience). In addition to all the motivations of, and constraints faced by the university in the CTD type, the university in the ITT type may also feel an obligation to support a local firm in a technical area where the firm has no other option. This obligation is partially guided by its charter and partially due to obligations created by earlier interactions and friendly relations between the firm and university The university also wishes to teach the firm the new technology, so that it can handle such projects on its own in future, and so that the new technology spreads in the country

In the JTD type, on being approached with a loosely defined joint product development project by the firm, the university examines it with the firm in depth to understand the nature of the problem and to define the scope of work required. During this examination, the university realises its strategic importance of the project in its linkage with the strategic goals of the university. It sees the opportunity in the project to work at the cutting edge of technology in the field and develop pioneering new technology with immediate practical application Apart from the motivations of, and constraints faced by the university in the CTD and ITT types, the university scientist in the JTD type is personally motivated by the creative nature of the joint product development project which is both academically exciting and of practical value It has high research potential, with possibly publishable nature of output and scope for adding to the university's resources

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Table 3 about here

4.3 DFI's selection criteria and role

A comparative analysis of the DFI's selection process and its role in adding value to the joint product development project in the three ideal types is presented in Table 3 A university-firm joint product development project is selected for financing if it fits the DFI's financing criteria in that it is technically sound, has some innovative content, adequate justification and a market that is potentially exploitable by the firm. The DFI checks that the firm and university are adequately interested in the project and are willing to spare the time to implement it. In addition, if the DFI has had earlier interaction with the university and/or the firm, if there is evidence of a good personal rapport between the firm and university emerging from earlier interaction between them, these are positively considered by the DFI. These factors add to the DFI's confidence in the firm and university implementing and completing the project satisfactorily.

The above selection criteria of the DFI are common across the three ideal types. In addition to these, factors peculiar to each type are also considered. In the CTD type, since several joint product development projects are proposed, the DFI checks whether the facilities being developed for them are applicable across projects and can be utilised in future. If so, this is considered positively. In the ITT type, he learning benefit for the firm through the universities teaching and interaction is a central component of the project and is considered positively in the DFI's evaluation. Similarly, in the JTD project apart from the learning benefits for the firm, the potential of the project in developing pioneering new technology is considered positively.

The DFI is part of the "technological infrastructure" (Weiss and Birnbaum 1989) for the firm and the university. It provides support for all proposed joint product development projects in developing the project proposal and in providing technical advice both directly and through an external consultant appointed by it for technically examining the merits of the project. While the project scope, roles and division of work between the firm and university in a CTD project is fairly clear from the onset, in an ITT project the DFI may assist the two in mutually defining the project scope and the roles of the two, and therefore act as a project facilitator In the JTD type, since the scope of the project is not very clear in the beginning and usually expands over time, the DFI may assist the two, as in the ITT case, in mutually defining the initial scope of the project and also support them during the expansion of the project scope at a later stage, or if the project reaches a crisis situation Thus apart from being a project facilitator the DFI can also become an active contributor to the project. In all types the basic role of the DFI as a financial catalyst to the joint product development project remains.

Table 4 about here

4.4 Project implementation structure and process

A comparison of the implementation process of the joint product development project in the three ideal types is shown in Table 4. In the CTD type, since the firm contracts out the basic research part of several product development projects completely to a university, it is essential that the project technology and nature of work be such that the basic research and applied R&D parts are clearly independent and sequentially dividable between the university and the firm. The firm takes a technology transfer from the university of those projects where the basic research is successfully completed. Therefore the basic research output of the university should be easily transferable in a one-time interaction so that the firm can independently work on applied R&D This also means that there should be low tacit knowledge component in the technology, as tacit knowledge cannot be developed in the short duration interaction.

In contrast to this, in the ITT type, the technical knowledge in the university is transferred to the firm through the teaching and intensive interaction throughout the project duration. There is usually a high tacit component in this technology and its learning requires constant interaction, self-experimentation, demonstration and teaching Therefore being in close vicinity of the university is important for the firm The university acts as a consultant and guides the firm in a number of technical areas in the project and in building its laboratory in the new technology area. In the JTD type, the firm and university both must have clearly complementary expertise and infrastructure that cannot be acquired by the other. This makes the two pool their resources and jointly develop the new product while creating new technology. They also use each other's infrastructure during the project. Apart from development of both tacit and explicit knowledge by both university and firm - they jointly create new knowledge and new technology during the project.

The viability of the implementation process of the three ideal types of joint product development projects depends on different factors. In the CTD type it is essential for the university to have clearly superior expertise, capability and cost advantage in doing basic research, compared to the firm doing the same. Also, compared to the university, the firm should have clearly superior expertise, capability and cost advantage in doing applied R&D. If this does not hold, then it is more viable for one or the other to do the entire project on its own Similarly in the ITT type, the university should have the required superior expertise and capability to guide the firm, compared to the firm learning the technology on its own. While the same applies to the JTD type, it is also essential that, given the loose definition of the project scope at the beginning of the project, the agreement between the firm and university is open ended, enabling them to seize technical and business opportunities that emerge during the project process. These opportunities naturally expand the scope of the project The DFI's role in supporting such scope expansion is very important. To be initiated, however, the JTD project must be one where, though the perceived risk is high, the apriori perceived benefits outweigh the perceived risk.

The product development activity in the three ideal types moves in different ways In the CTD type, it is uni-directional, with work at university (basic research) followed by technology transfer to firm, followed by work at firm (applied R&D). In the other two types the process is bi-directional and interactional. In the ITT type, work at the firm and at the university go on throughout the project, with constant back and forth movement of information and university to firm teaching interaction. In the JTD type, the process is identical to the ITT type, except that learning through interaction is equal in both directions (each teaching the other complementary past knowledge) and the interaction leads to the firm and university jointly creating new technology.

Initial project work in the CTD type is the basic research activity carried out at the university, during which it only report results periodically to the firm and rarely interact with it. The firm is only involved in keeping tract of the university's work through such reports. In the ITT type, initial project work at the university is in testing the designs developed by the firm, developing designs, and holding demonstrations for the firm's participants. At the firm, initial work is for checking on the production feasibility of the university's designs and their market suitability. The firm and university are together initially involved in discussions on choice decisions on design and equipment. In the JTD type the initial project work at both the university and firm is in developing facilities, capabilities and new technology for immediate and future application, and this involved working together with highly frequent and intense interaction. This process continues even in the later part of the project, though the project scope usually expands and the nature of work changes over the project duration.

Technology transfer in the JTD type is throughout the evolution of the project and is in both directions - firm to university and university to firm. In the ITT type also, technology transfer occurs throughout the project duration, but is largely in the university to firm direction. In the CTD type, the technology transfer takes place only in a well-defined short time interval after the university completes the basic research part of the project - followed by the later phase of project work in which the firm works independently on applied R&D. The university's role in the later phase is only to answer the rare queries from the firm that were not covered in the technology transfer phase. In the ITT and JTD types there is no clearly defined later phase as in the CTD type. In the ITT type, the project work and interaction process continue as earlier, with greater quantum of work at the firm as it learns the new technology and applies it. The university gets involved in checking results sent by the firm and they work together on experimenting on the completed product and in setting up a new laboratory at the firm. In the JTD type the project work at both the university and firm changes as the scope of the joint product development project expands. New areas of research emerge for the university and new areas of application of the new technology emerge for the firm.

In the CTD type, problems during the joint product development project are related to delays in project implementation. These are usually seen as one-time problems that have to be coped with by the participants rather than resolved. The physical distance between firm and university and the low communication during the project also make it difficult for such problems to be resolved. In the ITT type, problems are related to communication gaps and project delays. These are usually resolved rapidly through amicable discussions. Their rapid resolution is aided by the constant interaction between the firm and university throughout the project duration. In the JTD type, problems are related to the ambiguousness and change of project definition apart from communication gaps and delays - here project leaders take a proactive role in the prevention of such problems and in their rapid amicable resolution.

Table 5 about here

4.5 Learning processes

A comparative analysis of the learning processes in the three ideal types of joint product development projects is presented in Table 5 The learning processes are examined in three parts - within the university, during technology transfer and within the firm In all the three ideal types, learning within the university is through the high interaction between the scientists who learn from each other In the CTD type, the university scientists also learn to apply their knowledge to a practical problem and gain in practical experience and practice knowledge. In the ITT type, apart from these, the university scientists also learn by the process of teaching the technology to the firm In the JTD type the university scientists learn through the experience of new knowledge creation with tacit learning and by their exposure to practice. The firm and the university learn together by teaching each other complementary past knowledge. There is equal learning for both the firm and university as they gain both tacit and practical knowledge. In the ITT type, the learning together is through frequent interaction with both formal and informal training, demonstrations and practical experience with tacit learning. In the CTD type, the learning during the technology transfer phase is through demonstrations in which the firm's scientists learn by watching and questioning the university scientists and then trying out the same on their own - however, there is limited transfer of experience as this interaction is for a relatively short period Learning within the firm in the CTD type is through high interaction within the project group, which learns by applying its knowledge to practice and gains in practical experience and practical knowledge. In the ITT type, learning is by instruction and by doing as they learn to apply advanced technology to practice. They also learn about new equipment while purchasing them and using them. In the JTD type, the learning processes at the firm are identical to those at the university, with the difference that, at the firm they get an exposure to the research literature in their area, while at the university they get an exposure to industrial practice

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Table 6 about here

4.6 Post-project evaluation

A comparative analysis of the parameters of evaluation of the firm and the university of each other on completion of the joint product development project in the three ideal types is presented in Table 6 In the CTD type, post-project evaluation of the university by the firm is based on whether the criteria used for initially selecting the university held true during the project These include confidentiality, speed of implementation and timely completion of the project. Also success in the project, or success rates in the case of multiple projects, are evaluation criteria, as these have important viability implications also. In the ITT type, the firm's evaluation is essentially against its initial motivations and perceived benefits. It is also based on the ability of the university participants to teach effectively, implement their part of the project effectively, and the quality and ease of the firm's interaction with them. In the JTD type, apart from ease of interaction with the university, the firm's evaluation is also based on the ability of the university to understand the complexity of the product development problems faced by it, to give them better definition, and to develop and implement new technological solutions to solve them jointly. In all three types, evaluation by the firm is also based on the perceived knowledge base of the university

In all three types, the post- project evaluation of the firm by the university is based on its clarity in communicating its requirements and expectations. In the CTD type, it is also based on the presence of an adequate knowledge base among the firm's scientists to enable easy and rapid technology transfer. In the ITT type, the university's evaluation is against its initial motivations and perceived benefits. It is also based on the interest, ability and adequate starting knowledge base of the firm to absorb the new technology, as well as the ease of interaction with its personnel. In the JTD type, apart from these, the firm is evaluated on its ability to contribute equal and complementary resources effectively The openness in the firm to the suggestions made by the university and its patience and understanding in accepting the uncertainty of product development with both successes and failure is considered positively by the university.

5. Conclusions and directions for future research

This paper proposes a process typology and comparative analysis of the initiation, implementation process and evaluation of three ideal types of university-firm joint product development projects derived inductively from empirical case research. The typology frame, the comparison tables and the accompanying descriptions show the internal consistency within each ideal type and the contrasts across the ideal types. Given initial conditions, firms, universities and DFIs can use these as "templates" in planning their roles in initiating, executing and sustaining their joint product development projects.

This research contributes to our understanding of the management of university-firm joint product development projects. It complements the content studies of such projects that have provided an overview of the firm and university motivations, have explained the existence of such joint product development projects and their consequences, but have not been designed to understand their *implementation process*. Apart from proposing a process typology of such projects, this research meets this gap by providing a clear link between the identified project antecedent conditions, the process of initiation and implementation of the project, and further to its identified consequences. This research therefore provides both methodology and direction for future research in establishing this important link in other forms of joint product development projects.

As this research was of an exploratory nature, I stopped after developing the empirical base and using it for identifying the process typology and developing a comparative analysis. While sufficient cases were developed in this research to ensure external validity, further large sample research is required to test the validity, accuracy, completeness and robustness of the proposed process typology and its identified components and sub-processes. Other interesting avenues for future research are: (a) empirically identifying and describing the fourth ideal type derived from the typology frame, (b) testing the adequacy of the variables included in the process typology, (c) developing similar process typologies of other forms of joint product development projects, and (d) comparative development of the proposed typology with other typologies of joint activity between organisations (Millar, Demaid and Quintas, 1997).

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Figure 1
Process typology of university-firm joint product development projects

Initial Conditions	Firm has high technical knowledge but low contextual knowledge	Firm has high contextual knowledge but low technical knowledge
University has High technical knowledge But low contextual knowledge	Type 1 *"Contract Technology Development"* <u>Project Process</u>: University applies its technical knowledge to front-end basic research, passes results to firm, firm then applies its technical knowledge for scale-up product development. Project involves sequential work. <u>Outcomes</u>: Both firm and university utilise technical knowledge and broaden it. Both gain contextual knowledge.	Type 2 *"Interactive Technology Transfer"* <u>Project Process</u>: University applies its technical knowledge to firm's contextual product development requirements. Firm provides contextual knowledge to guide university. Project involves parallel interactive work. <u>Outcomes</u>: Firm gains technical knowledge. University gains contextual knowledge.
University has high contextual knowledge but low technical knowledge	Type 4 ? <u>Project Process</u>: University applies its contextual knowledge to the firm's technical product development requirements. Firm provides technical knowledge to guide university. Project involves parallel interactive work. <u>Outcomes</u>: University gains technical knowledge. Firm gains contextual knowledge	Type 3 *"Joint Technology Development"* <u>Project Process</u>: University and firm develop product jointly using complementary contextual knowledge in an area where the technical knowledge of both is low and needs development. Project involves interactive joint work. <u>Outcomes</u>: Both firm and university develop technical knowledge.

Table 1
Comparative analysis firm related factors

Project Features	*Contract Technology Development*	*Interactive Technology Transfer*	*Joint Technology Development*
Importance level of project for firm	Commercial importance; firm needs to expand project portfolio to have sufficient new products	Strategic importance, firm needs to learn technology to meet present and future product/market needs	Strategic and critical importance, firm needs to develop and learn new technology as old technology is obsolete
Familiarity with technology area	Familiar to firm	Unfamiliar to firm	New to firm
Need for firm to partly outsource product development	Lack adequate manpower and/or equipment	Lack required knowledge and appropriate manpower and/or equipment	Lack part of required knowledge and appropriate 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 markets	Skill available with university, rapid learning by doing, knows university well, frequent interaction possible	New technology required for market leadership and growth as world-wide technology is inadequate or inappropriate
Firm's major constraints	Lacks adequate resources for basic research in all projects of a large project portfolio or cannot spare the resources	Skill and equipment not available within firm, difficult to learn technology on its own	Persistent problems with present technology, cannot take technology leap on its own
Firm's choice of university primarily based on	Adequacy of the facilities, confidentiality and reputation, credibility in finishing project in time	Fruitful past interaction, rapport, ease of interaction, facilities are available at university, regular and close interaction is possible	Personal contact, earlier fruitful interaction, ease of interaction, interpersonal rapport, recommendations
Firm approaches DFI primarily	To expand portfolio of concurrent projects, reduce investment risk	As it cannot make entire investment on its own, risk factor not important	Due to high risk nature of project, cannot make entire investment on its own

Table 2
Comparative analysis technology university related factors

Project Features	*Contract Technology Development*	*Interactive Technology Transfer*	*Joint Technology Development*
Importance level of project for university	Commercial importance to the university and one of a stream of such projects for the university	Of more than just commercial importance to the university, seen as one of a series of ongoing interactions with the firm	Strategic importance to the university; seen as an opportunity to work at the cutting edge of technology in the field
Familiarity with technology area	Familiar to university	Familiar to university	New to university
University's considerations	To keep in touch with industry, apply knowledge, earn revenue, train students or junior scientists, advance work in their area	To continue ongoing interaction, apply knowledge, earn revenue, train students or junior scientists to apply knowledge, advance work in their area	Creative nature of project, high research potential, scope to add to university's resources, publishable nature, academically exciting
University's criteria	Project should fall within areas of research and experience base, time constraint due to teaching workload and other projects	Project should fall within areas of research and experience base, obligation to local firm, time constraint due to teaching workload and other projects	Project must fall within areas of research and available facilities, fall within experience base, friendly obligation, time constraint

Table 3
Comparative analysis: DFI's selection criteria and role

Project Features	*Contract Technology Development*	*Interactive Technology Transfer*	*Joint Technology Development*
Selection by DFI - common factors	Project fits financing criteria, has innovative content, adequate justification, potentially exploitable market; both university and firm have adequate and complementary facilities, trained manpower and sufficient time. DFI's earlier interaction, good rapport between firm and university, and high interest in the project		
Selection by DFI - additional factors	New facility has utility for future projects or is a multi-purpose facility.	Learning benefits for firm	Learning benefits for the firm potential for developing new technology
Additional benefits from DFI	Help in developing proposal and refining project concepts, external consultant's advice	Help in developing proposal and refining project concepts, external consultant's advice, defining project scope	Help in developing proposal and refining project concepts, external consultant's advice, defining project scope, support during expansion of project scope and project crisis
DFI's roles	Financial catalyst	Financial catalyst and project facilitator	Financial catalyst, project facilitator and contributor

Table 4
Comparative analysis: project implementation structure and process

Project Features	*Contract Technology Development*	*Interactive Technology Transfer*	*Joint Technology Development*
Requirement for the project process mode (feasibility)	Clearly, independent sequentially dividable work, output easily transferable to firm, low tacit knowledge component	Required technology and knowledge is transferable through teaching and the interaction process	Clearly complementary skills and equipment/ infrastructure in both firm and university which cannot be easily acquired by each other
Essential for project process mode (viability)	In its part of the project each has clearly superior expertise, capability and cost advantage compared to the other	The university has the required superior technical expertise and capability to guide the firm	Open ended agreement to seize emerging opportunities, apriori perceived benefits outweigh high risk
Project implementation structure	Basic research contracted to university, university implements it independently, if successful firm takes technology transfer, firm then works independently on applied R&D till commercialisation	University on a consulting contract, university teaches new technology and demonstrates its use, advises firm on purchase of equipment, firm works with university's guidance	Jointly work on developing new product, use of each other's laboratory and infrastructure, joint creation of new technology
Project implementation process	Work at university followed by university to firm technology transfer followed by work at firm	Work at university interactively moving with university to firm teaching interaction interactively moving with work at firm	Work at university interactively moving with joint technology creation interactively moving with work at firm
Initial activity at university	Experimentation and refinement of technology	Testing and design, teaching firm participants	Developing facility capability and new technology
Initial activity together	Low communication, No interaction	Discussion for choice decisions on design and equipment	Working together, high interaction, frequent meeting
Initial activity at Firm	Keeping track of university work through reports	Checking designs for production feasibility and market suitability	Developing new technology for immediate and future application

Table 4 (continued)
Comparative analysis project implementation structure and process

Project Features	*Contract Technology Development*	*Interactive Technology Transfer*	*Joint Technology Development*
Technology transfer activity	During short period of intensive interaction at university, from university to firm	Throughout the project duration, from university to firm	Throughout the evolution of the project in both directions
Later activity at university	Answer queries from firm not covered in the technology transfer phase	Checking interim design changes and results sent by firm	Work on expanding scope of project and new areas of research
Later activity together	Only clarification related communication, no interaction	Purchase of new equipment, checking completed product, experimentation	Working together on expanding scope of project, high interaction, frequent meeting
Later activity at firm	Applied R&D, work for changes to suit market requirements and resource constraints	Applying new technology using new equipment to develop product	Working on expanding scope of project as new applications emerge
Problems and their resolution	Related to delays in project implementation, seen as one time problems, coped with rather than solved	Related to communication gaps and project delays, resolved rapidly through amicable discussions	Related to the ambiguousness and change of project definition, communication gaps and delays, leaders take proactive role in prevention and in rapid amicable resolution

Table 5
Comparative analysis: learning processes

Project Features	*Contract Technology Development*	*Interactive Technology Transfer*	*Joint Technology Development*
Learning at university through	High interaction within project group, learning to apply knowledge to practice, gain in practical experience and practical knowledge	High interaction between scientists, learning from each other and from teaching, learning to apply knowledge to practice, gain in practical experience	High interaction between scientists, learning from each other, new knowledge creation, new experience, tacit learning, exposure to practice
Learning during technology transfer through	Demonstration, firm learns by watching, doing and questioning, tapping on university's experience, limited transfer of experience, no tacit knowledge developed by firm	Frequent interaction, formal and informal training, demonstrations, practical experience, tacit knowledge developed by firm	Teaching each other complementary past knowledge, creating new knowledge together, learning together, equal learning for both, tacit and practical knowledge developed by both
Learning at firm through	High interaction within project group, learning to apply knowledge to practice, gain in practical experience and practical knowledge	Instruction and by doing, learning to apply advanced technology to practice, learning about new equipment while purchasing them	High interaction within project group, learning from each other, new knowledge creation, new experience, tacit learning, exposure to research literature

Table 6
Comparative analysis: post-project evaluation

Project Features	*Contract Technology Development*	*Interactive Technology Transfer*	*Joint Technology Development*
Evaluation of university by firm based on	University's knowledge base, maintaining confidentiality, speed of implementation, against project success parameters and success rate in multiple projects	University's knowledge base, against initial motivations and perceived benefits, quality and ease of interaction, ability to teach effectively, effective project implementation	University's knowledge base, quality and ease of interaction, ability to understand problem complexity and develop and implement new technological solutions
Evaluation of firm by university based on	Clarity in communicating requirements, ease of technology transfer, adequate knowledge for ease in technology transfer	Clarity in communicating requirements, against initial motivations and perceived benefits, ease of interaction, interest and ability to absorb new technology, adequate knowledge base	Clarity in communicating requirements and expectations, ease of interaction interest and ability to contribute complementary resources effectively, openness and patience