Developing and Managing University-Industry Research Collaborations through a Process Methodology/Industrial Sector Approach

Simon P. Philbin, PhD, MBA
Programme Director, Institute of Shock Physics &
Visiting Fellow, Imperial College Business School
Imperial College London
South Kensington, London
SW7 2AZ
United Kingdom
Tel: +44 (0)20 759 48605
Email: s.philbin@imperial.ac.uk

Authors' Note

The author acknowledges the support of members of academic faculty from Imperial College London as well as other professional services colleagues. A previous version of this paper was presented at the 2009 SRA International Annual Event and Symposium, Seattle, Washington.

Abstract

A management framework has been successfully utilized at Imperial College London in the United Kingdom to improve the process for developing and managing university-industry research collaborations. The framework has been part of a systematic approach to increase the level of research contracts from industrial sources, to strengthen the university's academic base, and to diversify the provision of research at the university. This management approach is composed of two main platforms of activity: an industrial sector or channel focus (sector platform) and structured management methodologies to facilitate the research collaboration process (process platform). Application of this combined management framework through an engineering program case study at the university helped to significantly increase the university's industrially funded research portfolio in the aerospace and defense sector. Evaluation of the framework against comparative models for collaboration revealed that the management system provides a broad coverage of knowledge, social and financial or cost-based factors. The framework has been demonstrated as a suitable tool for research administration staff and those involved with initiating and managing research collaborations.

Keywords: University-industry research collaboration; research development; research management.

Introduction

A large proportion of universities in the United States and Europe have traditionally focused on undergraduate education, with a lesser emphasis on research. This has largely been the case since many of these institutions were founded (Bozeman & Boardman, 2003). There are, however, a smaller but significant number of universities where considerable research is undertaken. Such universities tend to receive research funding from a range of sources, including government organizations, charitable foundations, philanthropic donations, and industry (D'Este & Patel, 2007). This latter source is likely to include industrial funding for contract research, collaborative research projects, consultancy and technical advisory work, as well as the development of intellectual property through licensing of patents and other commercial activities (Perkmann & Walsh, 2007). The ability for universities to develop such commercial activities has a number of benefits; however, competition among academic institutions can be intense (Wimsatt, Trice, & Langley, 2009), and the success rate for proposals submitted to industry is often low.

The benefits for universities in undertaking commercial projects include access to additional financial resources to fund doctoral and post-doctoral positions; the potential to develop intellectual property; the provision of an application context for research (with application-specific data and information provided by the company); as well as the ability to generate research that results in journal publications and conference papers. Therefore, universities are increasingly interested in positioning themselves favourably with potential commercial partners and in converting research opportunities into funded projects that may ultimately lead to long-term, sustainable collaborations.

This paper describes a combined process methodology/industrial sector management framework that has been successfully deployed at Imperial College London in the United Kingdom to improve the research development process and the management of industrially funded research collaborations. This has been part of a systematic approach to increase the financial value of research contracts from industrial sources, to strengthen the academic base, and to diversify the sources of research at the university. The strategy has helped produce collaborative research programs at the university worth approximately £20 million over a five-year period. Although these projects have been funded by companies, and so can be regarded as a form of contract research, the actual funding has largely originated from government sources, and the research involves a significant level of collaboration between the company and the university; therefore, it is appropriate to regard these as collaborative research programs. The programs involve collaborative research with industrial companies in the UK, where the company provided funds to the university and the projects have been focused on the aerospace and defense (A&D) industrial sector.

This combined process methodology/industrial sector management framework is composed of two main platforms of activity (Figure 1): The use of an industrial sector or channel focus (sector platform), and the development and deployment of structured process methodologies to help facilitate research collaboration (process platform).

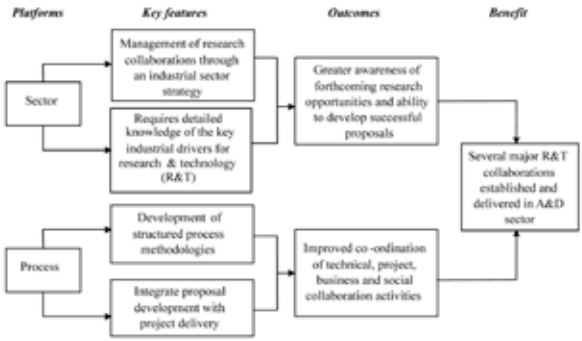

Figure 1. Combined process methodology/industrial sector management framework for managing and developing university-industry research collaborations.

The studies reported in this paper will not focus on the field of technology transfer (Siegel, Waldman, Atwater & Link, 2003), which more often refers to activities such as licensing agreements, start-ups and joint ventures

University-Industry Research Collaboration

Globally, there is increased competition among academic institutions, as university research groups compete with their peers to receive funding from large industrial companies to undertake research and technology (R&T) studies. This competition for funding and resources is prompting universities to improve their processes for developing and managing research collaborations with industry (Tucker, 2007). Industrial organizations work with universities to gain access to the intellectual knowledge and creative thinking within the academic environment (Sherwood & Covin, 2008). This can be regarded in terms of the open innovation model (Chesbrough, 2006), in which organizations increasingly partner with external sources for innovation. The motivation for companies is that the knowledge and academic thinking within universities can be utilized to deliver R&T, which can then help them improve their competitive positioning from building technology capabilities (Dooley & Kirk, 2007) through developing enhanced products or services. Industrial organizations are, however, required to justify research funding for universities, and so there is a greater need to capture the wider benefits of such collaboration, i.e., improving the skills and knowledge of the company's staff through knowledge transfer as well as the potential recruitment of technically qualified graduate students as new employees.

The merits of partnering between universities and companies have been explored in the literature. Kleyn, Kitney & Atun (2007) elucidated certain critical factors that contribute to successful university-industry partnerships in the life sciences sector, including leadership, organisational structure and operational management. The premise is that improvement in these factors can enhance the effectiveness of partnering, thereby improving innovation in research. Partnerships may also be regarded in terms of strategic alliances, where organizations cooperatively share knowledge and resources to gain competitive advantage (Ireland, Hitt & Vaidyanath, 2002). Moreover, Hitt, Ireland and Santoro (2004) have proposed a conceptual model, where alliance development and management effectiveness are supported by optimal resource configuration and exploitation mechanisms that allow value to be created by the alliance, and which build on information sharing and trust.

University-industry alliances can also be used to facilitate collaborative research projects, since sharing research can create value for both partners (Jarillo, 1988). Therefore, the development of strategic alliances can be an attractive way for organizations to grow their commercial activities (Sampson, 2007). However, harnessing knowledge from individuals outside an organization can present its own challenges, and a counter argument is that the relationships that support such alliances can sometimes become a liability by decreasing the quality of knowledge provided (Anand, Glick, and Manz, 2002). Nevertheless, many studies identify the benefits to the innovation process derived from the successful management of alliances and partnerships (Walter, Lechner, and Kellermanns, 2007).

A number of studies have highlighted the role that social capital can play in alliances and collaboration (Koka & Prescott, 2002). Social capital, when including information sharing, trust, and regular and open communication, has been shown to promote alliance development (Hitt, Ireland & Santoro, 2004). Moreover, trust, in conjunction with the level of commitment between partners, has also been identified as a significant indicator of whether or not a university-industry collaboration will be renewed (Plewa & Quester, 2007). Furthermore, a lack of social connectedness may inhibit the development of university-industry collaborations. Thune (2007) has employed a network embeddedness approach to investigate the role of social capital in developing university-industry collaborations. This study viewed social capital as an underpinning ingredient that helps facilitate collaborations; where social capital is limited, the new collaborations can be seriously hampered.

The role of knowledge itself is also fundamentally important to the development and management of collaborations, especially in regard to a company's ability to assimilate knowledge arising from collaborative activities (Barbolla & Corredera, 2009). In this regard, studies have identified the need for more formal mechanisms to enhance knowledge transfer, such as policies for intellectual property rights (IPR) as well as consideration of the relatedness of technology capabilities for the collaborating partners (Santoro & Bierly, 2006).

The effectiveness of knowledge transfer is influenced by its type. Explicit knowledge (e.g., data within a spreadsheet or database, or listed information and reports) is not particularly difficult to transfer; however, tacit knowledge can be more difficult to codify and transfer (Simonin, 1999). Such knowledge may, for example, be lacking when a researcher has not fully recorded all the fine details associated with successfully carrying out a certain materials spectroscopic technique. Consequently, for a collaboration to be effective, mechanisms to transfer tacit knowledge between collaborators need to be considered. Woods, Curran, Raghunathan & McKeever (2004) have identified a number of barriers to the transfer of tacit knowledge arising from university-industry collaborative research projects. These barriers include delays in achieving research objectives as well as differences between the university and the company regarding expectations for project progress; i.e., the company may have a more short-term horizon for fulfilment of the research goals. Therefore, the ability to address these barriers through appropriate mechanisms, such as enhanced communication between collaborators and improved measurement of the research outcomes, can contribute to an enhanced collaboration process.

Specific attributes of university-industry research collaboration have also been explored. Burnside and Witkin (2008) have reported on how IP negotiation can act as a barrier to new collaborations. They have proposed a process-driven approach to help academic faculty and contracts staff resolve negotiation issues. Kenney (1987) has examined the ethical dimensions of university-industry collaboration, and argues that universities should avoid becoming purely

research institutions, thereby compromising their ability to provide training and focusing on applied science at the expense of fundamental scientific research.

Having highlighted some key features of university-industry collaboration, it is now appropriate to explore the combined process methodology/industrial sector management framework. This framework, produced to facilitate the development and management of university-industry research collaborations, is composed of two 'platforms of activity:' the sector and process platforms.

Sector Platform

This platform uses an industrial sector strategy for the management of research opportunities and the delivery of research programs. Such a strategy is based on the premise that a number of benefits can be accrued through building up and then utilizing knowledge of a particular industry to initiate a greater (financial) level of research projects. A sector-based approach has been described as a best practice for channel management by Bellin (2006), who identifies the following successful elements of this structure: a market-driven approach based on customer needs; an overall management framework; an efficient balance of cost, control and coverage; a long-term perspective; a robust and high quality offer that is competitively priced; and the ease of doing business for all parties. These elements indicate there are benefits to be gained from managing the development and delivery of university-industry research collaborations according to an industrial sector (channel) strategy.

The sector approach, first established at Imperial College London in 2003, involved the creation of a new team of professional services staff (business development focused) within the university's Faculty of Engineering that would develop and manage university-industry collaborations according to industrial sectors. The team consisted of three research development executives and an administrator. Each of the executives focused on developing research collaborations in individual sectors, and the author was the executive charged with growing the volume of research projects for the A&D sector.

Previously within the university, business development staff had been based within individual academic departments, such as the Department of Chemical Engineering. This approach was sufficient when academic faculty required business support for small- and medium-sized research projects. However, to develop multidisciplinary and multi-departmental propositions for large and complex industrial programs, this approach was less effective. The new team, with its industrial sector approach, represented a departure from the previous strategy. The A&D sector was selected because a previous review of research strategy by the Faculty of Engineering had identified major funding opportunities in this sector, where the university would be well positioned to secure extensive participation (Philbin, 2004).

A lack of awareness of the key industry drivers for research in the area led to the decision to focus the research development team on to industrial sectors. In this regard, Baba, Shichijo & Sedita (2009) have highlighted how university-industry collaboration performance can be related to the ability of faculty teams to act as "boundary spanners," (page 759) combining scientific expertise with knowledge of the corporate enterprise. Boundary spanning could render the university more accessible to industry through improved communication of research capabilities and translation of university research into industrial

requirements. Leveraging knowledge of industrial sector applications for research therefore enables universities to improve their positioning with companies with respect to securing new research programs.

The sector platform involved the pursuit of an integrated set of activities to address a number of objectives: to raise awareness of the university's relevant research areas within the A&D sector; to make contact with key decision-makers in commercial and government organizations; to identify early stage research opportunities so the university could explore partnering approaches with candidate industrial collaborators; and to position the university to submit successful research proposals to companies with a view to undertaking A&D projects.

Table 1 provides details of the main activities of the sector platform. The activities are broken down according to internal or external focus, thus reflecting the dual focus of the sector platform approach. The need to drive the strategy according to external requirements to be industry sector aligned must be accompanied by a corresponding internal alignment that translates external requirements into internal opportunities, which can then be communicated to interested academic faculty members. The research development strategy relies on an ability to gain the support of relevant academic faculty, since it is through their laboratories, researchers and students that research will be undertaken. This internal/external dimension can be extended further in terms of the customer base for research development work. External customers are required to provide the funding opportunities and the industrial collaboration, but the academic faculty members will deliver the research studies. Such faculty can therefore be regarded as internal customers for the research development service, and consequently efforts need to be maintained to ensure that their needs are met.

Table 1. Main Activities Undertaken as Part of the Sector Platform

Internal activities	External activities
1. Identification of A&D research areas across the engineering departments at the university, together with identification of the corresponding members of faculty who either currently worked with the A&D sector or who wished to. 2. Development of a database of A&D research areas, where the areas were categorized according to sector-specific themes. The database included key information such as the principal investigator, department, research area description, A&D application area (existing or potential) and details of existing funding. 3. Presentations to departmental research committees involving senior members of faculty on the A&D research development strategy. These committee meetings allowed key academic stakeholders to be briefed on the overall approach. 4. Formation of application focused teams of faculty staff, which were aligned to specific A&D areas, such as autonomous systems. 5. Consultation with professional services staff within the university on how the A&D approach related to other corporate development initiatives.	1. Attendance at A&D conferences focused on R&T across the UK, continental Europe and also in USA. Such conferences provided networking opportunities and also helped to identify key industrial and government requirements for A&D research programs. 2. Attendance at government led procurement and research contracting events, where research opportunities as well as potential collaboration partners could be identified. 3. Articles published on the A&D strategy employed, so as to raise the profile of the university in this area (Philbin, 2004 and 2007). 4. Presentations given at research conferences and industry meetings on the university's A&D research capabilities. 5. Briefings and meetings held individually with prospective industrial collaborators, where research propositions could be presented. 6. Production and distribution of a research booklet that highlighted the A&D research areas. 7. Development of website pages as part of the Faculty of Engineering website, which included the material from the research booklet.

Translating the external A&D requirements into research opportunities was contingent on understanding how the research areas within the university related to the technology applications that both government and industrial stakeholders perceived as investment priorities. Figure 2 provides a schematic view of the research building blocks identified in the Faculty of Engineering, together with the aerospace and defense application areas. This view illustrates the technical areas that were explored and developed as part of the sector platform approach within the research development management framework.

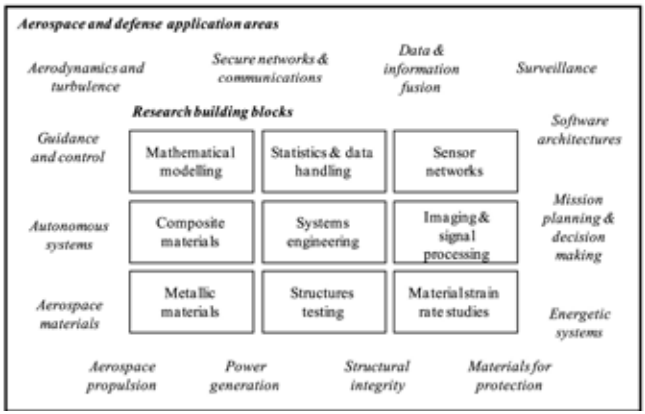

Figure 2. View of A&D application areas and university research areas (Philbin, 2007).

Process Platform

This platform employs structured process methodologies to help improve university-industry research collaborations. Previous work has identified a lack of process studies, especially in the area of university science parks (McAdam, Galbraith, McAdam & Humphreys, 2006) and technology transfer (Autio & Laamanen, 1995), and so this approach is an attempt to address that shortcoming. To develop a process methodology, a research study was undertaken involving interviews with 32 stakeholders for university-industry collaborations (Philbin, 2008a). Analysis of the interview findings, combined with the results of a literature review, revealed the conceptual model for university-industry research collaboration as a transformation process depicted in Figure 3.

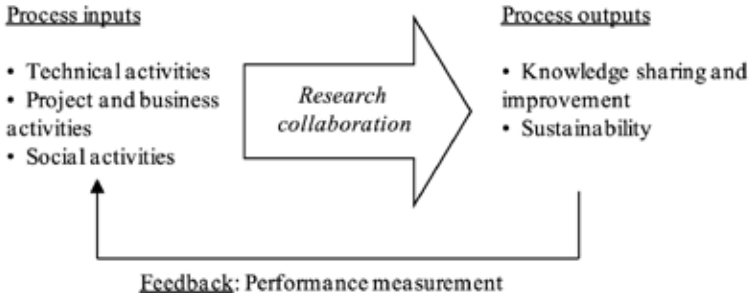

Figure 3. Transformation model of research collaboration (Philbin, 2008a).

The interview findings revealed that successful research collaborations are built on a number of process inputs that are technical, project and business, and social in nature. These inputs can be viewed as part of a transformation process that is research collaboration, and which gives rise to the desired process outputs, namely knowledge sharing and improvement, as well as sustainability. Not all research projects need to lead to sustainability, and some may need to cease for a variety of reasons, not least because the original research objectives have been fully met. Nevertheless, achieving a sustainable collaboration that moves forward, which gradually develops and addresses new and more demanding research goals, can be a desired outcome for many academic research teams. Long-term collaboration with industry can provide continued access to funding for doctoral and postdoctoral fellowships, but collaboration also provides a valued context for research and application-specific data that can be used to validate academic research.

Through further analysis of the interview findings, it was possible to build on the simple transformation view of research collaboration to formulate a process-based model for university-industry research collaboration (see Figure 4).

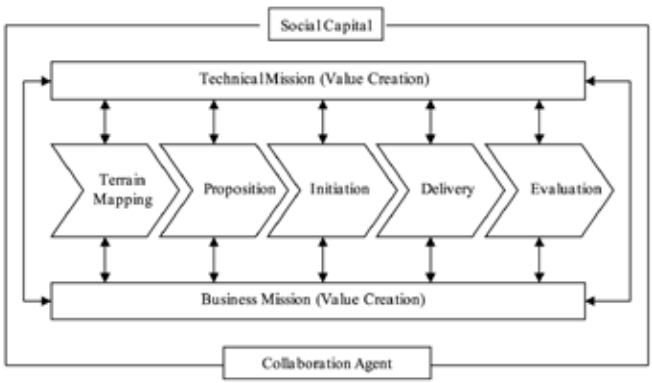

Figure 4. Process model for university-industry research collaboration (Philbin, 2008b).

The grounded theory for qualitative analysis (Strauss & Corbin, 1998) was employed to generate the conceptual process model, which related to both the empirical results and the literature on university-industry collaboration. The process model is based on a linear sequence of activities, starting with the terrain mapping stage and moving through proposition, initiation, delivery, and evaluation. The process is supported by four other elements: the technical and business missions, social capital, and the collaboration agent. The process was developed as a guide to help university-industry collaborators develop research collaborations and manage the resulting programs.

The following descriptions of the different components of the process model relate to a case study at the university. The terrain mapping and proposition stages involved broad-based activities, but the other components of the model are described for a particular research program valued at £3 million and delivered to an international engineering company.

Terrain Mapping

This stage, focused on knowledge acquisition of the A&D market for research, involved discussions with industrial stakeholders as well as gathering information on the requirements for long-term fundamental research in this sector. To accompany the external analysis, internal research and technology audits were conducted across the Faculty of Engineering, which allowed A&D research areas to be categorized into four main areas: information processing and management, systems research, aeronautics, and structures and materials. These categories were selected to ensure that the research areas could be grouped into sector-specific themes. Once this improved understanding had been established, it was possible to market the research areas through, for example, presentations and exhibitions at industrial events, such as the Farnborough International Air Show and Exhibition in the UK and at National Defense Industrial Association (NDIA) conferences in the US.

Proposition

At this stage, additional marketing-related activities focused on submitting defined research proposals to specific companies. This approach built on the knowledge gained from the terrain mapping stage. Moreover, informal discussions with key companies allowed proposals to be pitched at the right level; i.e. costs were at an appropriate financial level and the research proposals were focused on the most appropriate technology readiness level (TRL) that the industrial program required.

Initiation

Agreement with the company on the program statement of work, undertaken early on, allowed negotiation of the contractual terms and conditions to move ahead. A coordinated approach was used for the contracts negotiation, which involved signing an overall business agreement, as well as individual contracts for each of the nine research projects (which together constituted the research program). These contracts contained specific technical details and supporting costs.

Delivery

The individual research projects were assigned to academic principal investigators who were responsible for delivering the technical milestones to the company. Conversely, the collaboration agent provided overall financial management of the program and also had a customer liaison role with the company's managers. This liaison helped to ensure a consultative and timely approach to any problems.

Evaluation

Annual reviews of the three-year program were conducted, and there was also a major evaluation at the end that considered whether the research outputs were being incorporated into the company's technology development plans for future equipment. This approach led to a number of projects being awarded additional funding, which in some cases focused on an examination of the transition of the research findings into existing

and planned equipment systems. This was viewed by the company as being a particularly important outcome for the research, as it justified the research investment by demonstrating the added value to an actual equipment capability.

Technical Mission

Only technology areas that provided sufficient intellectual and academic rigour were investigated for possible collaboration with industry. This approach ensured that the research under investigation had the necessary potential to give rise to journal and conference proceeding papers of the required standard. Further, research was pursued that had a clear alignment to the company's technology requirements, thus maintaining the technical mission for both the company and university. Being able to demonstrate the relevance of the research to the company's technical objectives is clearly an important criterion for both initially gaining research funding and substantiating the industrial value to the research findings.

Business Mission

Careful consideration was applied to the proposal costs, and in a few cases the project scope was modified so more affordable proposals could be submitted. This flexibility helped improve the probability of the project being awarded, and also demonstrated commitment by the university to the research and to working with its industrial partner. Moreover, an alignment of the research areas with the company's priorities, which were in turn influenced by government procurement directives, allowed for the development of the business case for investment by the company in the research projects.

Social Capital

Contact made in the early stages of the process with key technical staff in the prospective collaborator organizations allowed social capital to be established and then nurtured. Furthermore, social capital was built up through regular contact with technical and contracts staff from the company. In fact, at one point, certain issues delaying the contractual negotiations could have resulted in a loss of program funding. However, through regular dialogue with the company's contracts manager, these issues were resolved quickly, which allowed the program to go ahead.

Collaboration Agent

The collaboration agent was the person within the university tasked with ensuring research programs were contractually awarded and then overseeing program delivery to ensure the company's overall program requirements were met. The author undertook this role, which allowed the academic faculty to concentrate on leading the individual research projects while giving the company a central point of contact to quickly resolve any issues.

Evaluating the Management Framework

Adoption of the management framework based on a combined process

methodology/industrial sector approach has resulted in a number of benefits for the university. Nevertheless, to evaluate the effectiveness and identify any limitations of the management framework, it is useful to compare to other approaches reported in the literature. Ireland, Hitt, & Vaidyanath (2002) examine effective alliances according to transaction cost economics (TCE), the resource-based view (RBV) of strategy, and social network (SN) theory. Although research collaborations can be regarded as a simpler version of more extensive strategic alliances, analysis through these three theories still provides an appropriate and broad-based method to consider management frameworks for university-industry collaborations.

TCE (Pessali, 2009) can be viewed in terms of the reduced costs incurred by a company through undertaking a research collaboration with a university. The company is able to utilize the academic resources of the university that it would otherwise not have had access to, and so is able to lower its costs. Collaborations will themselves incur transaction costs that must be accounted for; however, a company will seek to justify investment in university research either through potential future revenues from enhanced products or services to be developed or through the reduced costs from gaining access to the knowledge generated by the university. Moreover, companies may form stronger linkages with universities to reduce both the transaction and production costs of associated manufacturing operations (Barringer & Harrison, 2000).

The RBV theory of strategy (Wernerfelt, 1984) has been widely discussed in the literature across a broad range of management applications (Grant, 1998). Essentially, a firm's competitiveness can be related to its unique combination of organizational resources and assets. Improvements in competitiveness through developing new products or services can therefore be regarded in terms of a company's access to the required resources, e.g., people, infrastructure, and technology, as well as less tangible resources, such as tacit and explicit knowledge. Furthermore, Spender (1996) has extended the RBV paradigm to focus specifically on knowledge, where a firm's level of success can be attributed to its capacity to acquire, integrate and then deploy knowledge in support of technology developments for new products and services (Su, Chen, & Sha, 2007). Applying the RBV theory to research collaboration would essentially suggest that collaborative activities undertaken by companies help generate knowledge to improve a firm's competitiveness.

SN theory suggests that an organization's activities on a strategic level are contingent on the social context within which the organization operates (Gulati, 1999). Furthermore, the social connectedness associated with an organization includes both internal (intra-organizational) and external (inter-organizational) relationships (Madhok & Tallman, 1998). Extending SN theory to collaborations would suggest that university-industry interactions are likely to be linked to the level of social links between them, and that collaboration success will be a function of the extent and quality of social interaction.

It is now appropriate to compare the combined process methodology/ industrial sector management framework with other management systems for university-industry collaboration. Two different approaches to collaboration from the literature reflect different perspectives on university-industry relations. Burnside and Witkin's (2008) model for university-industry collaboration is linked to a need to establish a central intellectual property and industrial research alliance office. This department at the university focuses on

certain key objectives: build a team; work from the big picture (model); commit the team to a process (secure buy-in); work the process creatively; and have an escalation path. The model also emphasizes the need for effective negotiation of intellectual property rights (IPR), something that can cause substantial delays in the signing of collaboration agreements and research contracts.

The second comparative model is by Thune (2007), which involves a networkembeddedness approach to university-industry collaboration. This study draws on a social capital perspective to examine how access to an array of embedded resources derived from networks of relationships can have an impact on the formation of new collaborations, with the research indicating that such social interactions are central to both forming and carrying out such collaborations.

Table 2 illustrates how the three collaboration models relate to the aforementioned theoretical underpinnings.

Table 2. Comparison of the Combined Process Methodology/Industrial Sector Management Framework with Collaboration Models from the Literature

Theory	Combined Process/Sector Framework	Burnside and Witkin (2008)	Thune (2007)
TCE	The framework includes a focus on spanning the university research and industrial sector divide, which has the potential to improve the commercial attractiveness of the university research. The process model includes the 'business mission', which is also specifically aligned to emphasizing the commercial viability of the research; these commercial linkages help reinforce the TCE basis.	The model includes a pragmatic view on the negotiation of collaboration agreements with a particular focus on determination of optimal IP conditions. This negotiation framework should help ensure the commercial attractiveness of research propositions and hence be a positive TCE characteristic, although there does not appear to be a specific cost-based attribute to the model.	The approach did highlight the leading role that government agencies can play in stimulating research and this government support can help to reduce transactional costs for industrial sponsored research. There is therefore some coverage of the cost drivers for collaboration.
RBV	The framework includes a strong focus on the acquisition and deployment of knowledge. This includes sector-specific knowledge through the industrial focus as well as the gathering and utilization of knowledge in various parts of the process model (terrain mapping, proposition, technical mission, etc.).	The structured model includes consideration of knowledge generation, however, there does not appear to be a systemic treatment of the different forms of knowledge and the processes that can be utilized in order to facilitate collaboration as a knowledge driven activity.	Although there was coverage of the nature of knowledge flows as part of university-industry research collaboration, the approach did not have a systematic treatment of how knowledge can be effectively acquired and deployed in a collaboration context.
SN	Social capital as a feature of social networks is a clear component of the process model as well as the transformation process and hence the resulting framework takes account of the social dimensions of collaboration.	The model makes reference to the need to continually emphasize relationships rather than transactions, plus there is a clear development of the role of individuals in the collaboration process; This model therefore has a significant social applicability.	The model includes a clear analysis of the role of relationships across different types of collaborations, which have been developed according to different situations, such as needs-driven or opportunity-driven collaborations. The model therefore has a strong social dimension.

An analysis of the approaches to university-industry collaboration across the three supporting theories provides a useful perspective. The model by Burnside and Witkin (2008) offers a sound negotiation approach, whereas Thune's (2007) approach provides a rigorous treatment of the social dimensions of collaboration. Further analysis highlights how the combined process methodology/industrial sector management framework provides a comprehensive treatment of collaboration factors across a broad, systems-wide context. This spans coverage of the social inputs to collaboration, through considering relationships and key staff, as well as a focus on the economic and cost basis for collaboration and the resources and knowledge that need to be deployed. Both the initiation and delivery of collaborations can be highly contingent on an organization's ability to utilize its current and acquired knowledge resources; hence in this regard, the development of process and structural management models for collaboration needs to have an adequate consideration of knowledge as a central paradigm.

Conclusions

An innovative management framework was devised and employed at Imperial College London to improve the development and management of collaborative research programs. The combined process methodology/industrial sector management framework focused on the aerospace and defense industrial sector as part of the sector platform, which allowed significant knowledge build-up (both explicit and tacit) of the A&D industry that has traditionally been a strong provider of funding for academic research. This focus has allowed the university to pursue a co-ordinated marketing and bidding campaign with companies from the sector that has resulted in £20 million of research programs being awarded over a five-year period.

The combined process methodology/industrial sector management framework also included a systematic use of structured management methodologies as part of the process platform. This approach was informed by literature depicting research collaboration as a transformation process, which further allowed an overall process to be developed for the management of university-industry research collaborations.

The use of the management framework builds on studies reported in the literature, which highlight the lack of process models in the area of university-industry collaboration. From a broader perspective, companies are increasingly pursuing an agenda of open innovation, and this is leading to greater collaboration with universities. But with this greater opportunity for funded research comes competition between universities, as well as a need to improve the management of research development within universities. Literature studies also point to the role that social capital plays through building trust from open and regular communications between collaborators as well as honesty and so-called "norms of reciprocity" (Yli-Renko, Autio, & Sapienza, 2001, page 591).

Effective knowledge transfer is also a highly important determinant for successful collaborations. The management framework described in this paper is an attempt to tackle some of these issues, and to provide an intellectual foundation for professional services at universities engaged in helping academic faculty establish and manage collaborations with industry. The framework, crucially, is also practitioner focused and can be regarded as a guide to help maximise research opportunities and eventual levels of research contracts that a university may generate. The approaches described in this paper will also provide a useful insight for industrial managers who are involved with contracting university research.

Focusing research development activities according to an industrial sector approach involved the university positioning itself within the aerospace and defense sector as part of a co-ordinated marketing and bidding campaign. This phase of activity was clearly externally focused but it had to be conducted in parallel with communication and team building internally with the academic faculty. Without gaining the firm commitment of the academic faculty there would have been no point in pursuing the external company engagement since members of faculty are of course responsible for leading any resulting research studies.

The use of the process model highlighted that successful collaborations require an adequate focus to be applied to all parts of the model (although this is dependent on the size and scope of collaboration). Many of the model's elements were found to be inter-dependent, e.g. the collaboration agent required an open and honest relationship with the company, which was built on the required social capital. Moreover, focus needed to be maintained on the technical mission (e.g. through understanding and applying TRLs) as well as the business mission (e.g. understanding the customer's position on value for money). Throughout the process, social capital was built up steadily and this position helped alleviate a difficult point in the contractual negotiation stage (initiation). A weakness, however, for process models derived from qualitative results is that they can sometimes be normative (Strauss & Corbin, 1998). To address this weakness, the model contained both process components (terrain mapping, proposition, initiation, delivery and evaluation) and structural components (technical mission, business mission, social capital and collaboration agent), as well as being grounded on findings from supporting literature reviews.

Analysis of the combined process methodology/industrial sector management framework has been undertaken through comparison with collaboration models from the literature, including approaches by Burnside and Witkin (2008), and Thune (2007). This analysis has included assessment of the approaches according to three underpinning theoretical frameworks, which had been previously employed as part of an 'analysis lens' by Ireland, Hitt & Vaidyanath (2002). The analysis found that whilst the other approaches had distinct features and potential benefits for collaboration management, the combined process methodology/industrial sector management framework reported in this paper provides a comprehensive treatment of collaboration factors across transaction cost economics (TCE), resource-based view (RBV) of strategy, and social network (SN) theories. The management framework is therefore applicable to a range of university-industry collaboration scenarios.

The research and supporting case study investigation reported in this paper have revealed the benefits that can be derived from employing a management framework for research collaborations, based on the sector and process platforms approach. However, it is important that university management systems not become overly burdensome so that the creative aspects of scientific research and collaborative work are hampered or blocked. Ideally, research administration processes will operate alongside and in a supporting capacity to the academic and creative activities that are essential to the exploratory nature of scientific research. Moreover, research administration processes, such as those described in this paper, will complement creative academic work, improve the efficiency of how universities partner with companies, and help ensure that academic faculty are free to devote adequate time and energies to overseeing research activities.

It will not always be appropriate to employ an industrial sector strategy within a university, and such an approach will be contingent both on the university's current practice and its future aspirations. Where it is possible to manage research development according to industrial

sectors, this initiative may be viewed as a long-term strategy. The strategy will need to be adequately staffed over multiple years, and will require commitment from the university's senior management. . The industrial sector focus will also need the support and engagement of relevant academic faculty, and so communication and team building are crucial, as are relations with key external stakeholders.

The process model described previously is not meant to be overly rigid but ideally can be viewed as a guide to improve the management of research collaborations, from the opportunity stage through delivery. For universities looking to engage further with industrial companies, it is further recommended that efforts are directed towards building appropriate social relations with individuals from these prospective partners, including technical, commercial and business focused staff. There also needs to be careful thought towards enhancing the transfer of knowledge generated by the university to the company, so that collaborations can be developed into sustainable relationships. These activities do, of course, need to occur in addition to the delivery of individual research projects and programs through the key channels for knowledge dissemination (Cohen, Nelson, & Walsh, 2002), such as journal articles, conference papers, reports and patents, and informal information exchange.

There are a variety of reasons why collaborations may or may not be successful (Dodgson, 1992), and the development of major high-value research collaborations can often be a complex process that involves many people from both the university and company. The use of suitable management frameworks does, however, provide a potential guide so that the success rate for research proposals can be maximised and the risks of the resulting research projects mitigated.

Future work is suggested on the application of the management framework to other case studies, particularly those in the healthcare and pharmaceutical sectors. This will allow the merits of the approach to be explored from new perspectives and for its general application to different organizational and operational contexts to be examined in more detail. Future work is also suggested in developing an improved understanding of the value for money attributes for research collaborations, so that companies may justify the case for investment in university research and for universities to improve their ability to commercially engage with industrial organizations. Developing such areas of research will help to strengthen the theoretical basis for collaboration management, thereby contributing to advancement in the research administration profession.

References

Anand, V., Glick, W. H., & Manz, C. C. (2002). Thriving on the knowledge of outsiders: Tapping organizational social capital. *Academy of Management Executive, 16*(1), 87-101.

Autio, E., & Laamanen, T. (1995). Measurement and evaluation of technology transfer: Review of technology transfer mechanisms and indicators. *International Journal of Technology Management, 10* (7/8), 643-664.

Baba, Y., Schichijo, N., & Sedita, S. R. (2009). How do collaborations with universities affect firms' innovative performance? The role of "Pasteur scientists" in the advance materials field. *Research Policy. 38*(5), 756-764.

Barbolla, A. M. B., & Corredera, J. R. C. (2009). Critical factors for success in university-industry research projects. *Technology Analysis & Strategic Management, 21*(5), 599-616.

Barringer, B. R., & Harrison, J. S. (2000). Walking a tightrope: Creating value through interorganizational relationships. *Journal of Management, 26*(3), 367-403.

Bellin, H. (2006). Best practice channel management: The channel management framework. *Journal of Marketing Channels, 14*(1/2), 117-127.

Bozeman, B., & Boardman, P. C. (2003). Managing the new multipurpose, multidiscipline university research centers: institutional innovation in the academic community. IBM Center for the Business of Government: Transforming Organizations Series.

Burnside, B., &Witkin, L. (2008). Forging successful university-industry collaborations. *Research-Technology Management, 51*(2), 26-30.

Chesbrough, H. W. (2006). Open innovation: A new paradigm for understanding industrial innovation. In Chesbrough, H. W., Vanhaverbeke, W., & West, J. (Eds). *Open innovation: Researching a new paradigm*. Oxford: Oxford University Press.

Cohen, W. M., Nelson, R. R., & Walsh, J. P. (2002). Links and Impacts: The Influence of public Research on Industrial R&D. *Management Science, 48*(1), 1-23.

D'Este, P., & Patel, P. (2007). University-industry linkages in the UK: What are the factors determining the variety of interactions with industry? *Research Policy, 39*(6), 1295-1313.

Dodgson, M. (1992). Technological collaboration: Problems and pitfalls. *Technology Analysis & Strategic Management, 4*(1), 83-88.

Dooley, L., & Kirk, D. (2007). University-industry collaboration: Grafting the entrepreneurial paradigm onto academic structures. *European Journal of Innovation Management, 10*(3), 316-332.

Grant, R. M. (1998). Contemporary Strategy Analysis (third edn.), Oxford, Blackwell.

Gulati, R. (1999). Network location and learning: The influence of network resources and firm capabilities on alliance formation. *Strategic Management Journal, 20*(5), 397-420.

Hitt, M. A., Ireland R. D., & Santoro, M. (2004). Developing and managing strategic alliances, building social capital and creating value. In A. Ghobadian. N. O' Regan, D. Gallear, & H. Viney (Eds.). *Strategy and performance: Achieving competitive advantage in the global marketplace*. London: Palgrave-Macmillan Publishing.

Ireland, R. D., Hitt, M. A., & Vaidyanath, D. (2002). Alliance management as a source of competitive advantage. *Journal of Management, 28,* 413-446.

Jarillo, J. C. (1988). On strategic networks. *Strategic Management Journal, 9,* 31-41.

Kenney, M. (1987). The ethical dilemmas of university-industry collaborations. *Journal of Business Ethics, 6,* 127-135.

Kleyn, D., Kitney, R., & Atun, R. A. (2007). Partnership and innovation in the life sciences. *International Journal of Innovation Management, 11*(2), 323-347.

Koka, B. R., & Prescott, J. E. (2002). Strategic Alliances as Social Capital: A Multidimensional View. *Strategic Management Journal, 23*(9), 795-816.

Madhok, A., & Tallman, S. B. 1998. Resources, transactions and rents: Managing value through interfirm collaborative relationships. *Organization Science, 9*(3), 326-339.

McAdam, M., Galbraith, B., McAdam, R., & Humphreys, P. (2006). Business processes and networks in university incubators: A review and research agendas. *Technology Analysis & Strategic Management, 18*(5), 451-472.

Perkmann, M., & Walsh, K. (2007). University-industry relationships and open innovation: Towards a research agenda. International Journal of Management Reviews, 9(4), 259-280.

Pessali, H. F. (2009). Metaphors of Transaction Cost Economics. *Review of Social Economy, 67*(3), 313-328.

Philbin, S. (2004). Research opportunities. *Defence Management Journal, 27,* 76-78.

Philbin, S. (2007). Technology through collaboration. *Defence Management Journal, 38,* 10-12.

Philbin, S. (2008a). Measuring the performance of research collaborations. *Measuring Business Excellence, 12*(3), 16-23.

Philbin, S. (2008b). Process model for university-industry research collaboration. *European Journal of Innovation Management, 11*(4), 488-521.

Plewa, C., & Quester, P. (2007). Key drivers of university-industry relationships: The role of organisational compatibility and personal experience. *Journal of Services Marketing, 21*(5), 370-382.

Sampson, R. C. (2007). R&D Alliances and Firm Performance: The Impact of Technological Diversity and Alliance Organization on Innovation. *Academy of Management Journal, 50*(2), 364-386.

Santoro, M. D., & Bierly, III, P. E. (2006). Facilitators of knowledge transfer in university-industry collaborations: A knowledge-based perspective. *IEEE Transactions on Engineering Management, 53*(4), 495-507.

Sherwood, A. L., & Covin, J. G. (2008). Knowledge acquisition in university-industry alliances: An empirical investigation from a learning theory perspective. *Journal of Product Innovation Management, 25,* 162-179.

Siegel, D. A., Waldman, D. A., Atwater, L. E., & Link, A. N. (2003). Commercial knowledge transfers from universities to firms: Improving the effectiveness of university-industry collaboration. *Journal of High Technology Management Research, 14,* 111-133.

Simonin, B. L. (1999). Ambiguity and the process of knowledge transfer in strategic alliances. *Strategic Management Journal, 20,* 595-623.

Spender, J. C. (1996). Making knowledge the basis of a dynamic theory of the firm. *Strategic Management Journal, 17,* Winter Special Issue, 45-62.

Strauss, A., & Corbin, J. (1998). *Basics of qualitative research: Techniques and procedures for developing grounded theory.* London: Sage Publications.

Su, C.-T., Chen, Y.-H., & Sha, D. Y.-J. (2007). Managing products and customer knowledge in innovative new product development. *International Journal of Technology Management, 39*(1/2), 105-130.

Thune, T. (2007). University-industry collaboration: The network embeddedness approach. *Social and Public Policy, 34*(3), 158-168.

Tucker, R. C. (2007). Industry sponsored university research: An underutilized resource. *Advanced Materials and Processes, 165*(5), 78-81.

Walter, J., Lechner, C., & Kellermanns, F. W. (2007). Knowledge transfer between and within alliance partners: Private versus collective benefits of social capital. *Journal of Business Research, 60*(7), 698-710.

Wernerfelt, B. (1984). A resource-based view of the firm. *Strategic Management Journal, 5*(2), 171-180.

Wimsatt, L., Trice, A., & Langley, D. (2009). Faculty perspectives on academic work and administrative burden: implications for the design of effective support services. *Journal of Research Administration, 40*(1), 71-89.

Woods, K., Curran, R., Raghunathan, S., & McKeever, C. (2004). Barriers to the Success of Strategic University – Industry Collaborative Research Projects. *Proceedings of the American Institute of Aeronautics and Astronautics (AIAA), 4th Aviation Technology, Integration and Operations Forum, Chicago, Illinois, 20th – 22nd September 2004.*

Yli-Renko, H, Autio, E., & Sapienza, H. J. (2001). Social Capital, Knowledge Acquisition and Knowledge Exploitation in Young Technology-Based Firms. *Strategic Management Journal, 22*(6/7), 587-613.