Why do firms collaborate to develop technology?
There is a wide range of explanations as to why firms collaborate to develop technology. These includes change in industrial structures and systems of production, and more particularly the role of technology and innovation in this change. There are also economic explanations (cost reduction) and the competitive relationships between firms (competitor exclusion or locking-in key players), while other explanations are less instrumental and focus on qualitative issues such as organizational learning. Generally, however, from the perspective of the firm, technological collaboration is seen as a means of improving technological knowledge and skills.

Although technological collaboration occurs in many different forms, and may reflect different motives, a number of generalizable assumptions underpin it. The first is the belief that it can lead to positive sum gains in internal activities—that is, partners together can obtain mutual benefits that they could not achieve independently. Such benefits may include:

Increased scale and scope of activities. The outcomes of technological collaboration may be applicable to all partners' markets, and thus may expand individual firms' customer bases (increased scale). Synergies between firms' different technological competencies may produce better, more widely applicable products (increased scope). Increasing the scale of resources to technology development can also raise entry barriers to other firms.

Shared costs and risk: Technological collaboration can share the often very high costs, and therefore high risks, of technological development (although it also, of course, means future income streams are shared).

Improved ability to deal with complexity. As we have already seen, closer technological integration between firms is a means of dealing with the complexity of multiple sources and forms of technology. It allows, for example, for the better transfer of tacit knowledge by providing a mechanism whereby close linkages among different organizations enable the development of sympathetic systems, procedures, and vocabulary. It may also allow partners to 'unbundle' discrete technological assets for transfer .

A second assumption regarding collaboration concerns the way it assists with environmental uncertainty . Increasingly sophisticated and demanding customers, growing competition in and globalization of markets, and rapidly changing and disruptive technologies place pressures on firms to exist with, and attempt to control, these uncertainties. This is believed to be achieved more easily in collaboration than in isolation. BAA's collaboration with Laing O'Rourke to develop Terminal 5 at Heathrow airport would have resulted in unacceptable levels of uncertainty had the client and main contractor not engaged in a novel, collaborative agreement. A number of analyses of collaboration link it with uncertainties in the generation and early diffusion of new technologies (Freeman 1991). The PLC model of Abernathy and Utterback (1978), for example, implies a cyclical role for collaboration based on uncertainty. Thus, in early stages of development there are periods of high interaction between organizations, with many new entrant companies possessing technological advantages over incumbent firms, and extensive collaboration between firms until a 'dominant design' emerges in a technology. As the technology matures, uncertainty declines and collaborative activity recedes. The high level of

collaborative activity seen in the creation of technical standards is a means of reducing uncertainties by introducing interchangeable products and interfaces .

A third set of assumptions underlying collaboration concerns its flexibility and efficiencies compared to the alternatives. For example, collaboration may be an alternative to FDI, mergers, and acquisitions, which are difficult to change once entered into. As a governance structure, collaboration has advantages over the alternatives of arm's-length market transactions and vertical integration. It can allow firms to keep a watching brief on external technological developments without having to invest heavily. Large-firm–small-firm interaction can be facilitated such that the resource advantages of the former are linked to the behavioural or creative advantages of the latter, while each maintains its independence. A large drug company, for example, may choose to collaborate with our biotechnology firm as a means of developing its options, so that it can invest more heavily once the technology is better proven and better understood. The large firm will have gained the opportunity to learn about the technology during the collaboration. Potentially, there are numerous advantages from technological collaboration if these assumptions hold. That is not to deny the potentially adverse aspects of collaboration. Technological collaboration can be anticompetitive, by excluding certain firms, or raising entry barriers, or operating in the form of cartels that antitrust legislation prevented in the past. As discussed in relation to social capital, there may be strategic dangers from firms that become overly reliant on externally sourced rather than internally generated technology. Without internal technological competencies there can be no 'receptors' for external technology, nor capacity for building technological knowledge, which, apart from its other benefits, provides the basis for attracting future partners. Examining whether the potentials of collaboration are in practice being realized is difficult, as data on its extent and outcomes are often piecemeal and frequently contradictory. The bulk of evidence suggests an increasing role for technological collaboration in industry, but the majority of studies of its outcomes point to the considerable difficulties in achieving mutually satisfactory outcomes amongst the partners.

The extent of technological collaboration

Measuring the extent to which technological collaboration occurs is notoriously difficult. There are, however, numerous examples from around the world of increased collaborative activity. The encouragement of technological collaboration is a key policy focus of the European Commission, as seen in policies such as ESPRIT (a collaborative programme with an IT focus) and various Framework programmes (funded collaborative research in a range of industries) -in 2007 the European Commission was managing funding of Framework Programme 7. In the USA, SEMATECH provides an example of government-sponsored technological collaboration, and, in Canada, the Industrial Research Assistance Program (IRAP) encourages collaboration between firms and universities. In the UK, the DTI provided funding of just under $200 million for collaborative research between industry and research organizations in 2007. A wide range of technological collaborations also occurs in Japan, ranging from large-scale, high-technology schemes such as the FGCS Project to local support schemes in over 150 Regional Technology Centres. Taiwan's ITRI has played a central role in encouraging technological development and diffusion through collaborative projects. Large Korean firms are increasingly forming technological alliances with US, Japanese, and European firms (Sakakibara and Dodgson 2003; Dodgson, Mathews, and Kastelle 2006). Several databases on technological collaboration

measure the numbers of new international alliances announced in the technical press. These tend to under-represent collaborations based outside non-English-speaking countries. The best of these databases, the MERIT-CATI database, showed an increase in the number of new collaborations, from 189 in 1981 to 339 in 1991, and 602 in 2001 (NSB 2004). The majority of these new collaborations occurred in new technologies, particularly in IT and biotechnology, and were based in the USA, Japan, and Europe. The extent to which firms source technology externally, both vertically and horizontally, is affected by industrial structures. A commonly cited reason for the high levels of external integration in the Japanese industry, for example, is the structure of industry itself. The large business groups—the Keiretsu—control a wide range of diversified interests and can facilitate close trading relationships and cooperation and strong technological linkages between contractors and subcontractors.

The incidence of formal collaboration recorded in innovation surveys remains low, with only around 10 per cent of UK firms indicating they have formal collaborations for innovation. This partly results from many firms lacking the resources and absorptive capacity to work interactively with others (Tether 2002). Firms may also operate in sectors where issues of appropriability are so great that they mitigate the advantages of collaboration (Cassiman and Veugelers 2002). For those firms able to form formal collaborations, however, there can be significant performance benefits (Belderbos, Carree, and Lokshin 2004).

The challenges of managing technological collaboration

It is difficult to consider what constitutes success in managing technological collaboration, since the range of firms' circumstances, their expectations, and their experiences of collaboration are so varied. Some firms are content with satisfactory technological outcomes, others require bottom-line financial improvements as a result of their collaborative activity. In all cases, managing successful technological collaboration is a difficult task. This is because of changes over time during the course of collaborations and because of what can be called the 'technology collaboration paradox'. Although the management challenges discussed here relate to formal technological collaborations, they can also apply in some circumstances to managing networks and communities more generally. The changes that can occur during the course of a technological collaboration are similar to those that can affect all joint ventures and include:

Changing aims of collaboration.

Changing bargaining power of partners.

Obsolescence of the original reasons for forming the collaboration.

Initial focus on the wrong sets of issues.

The technological collaboration paradox derives from the way in which one of the greatest attractions of collaboration is the possibility of learning from partners. Organizations learn more

from dissimilar organizations, where technologies, cultures, management practices, and strategies are different and where the opportunities for learning are therefore greater. A small firm may be attracted to working with a large firm because of its high levels of resources and well-established operational procedures. Alternatively, the large firm may be attracted to working with the small firm because of its flexibility and entrepreneurialism. Private-sector firms may be attracted to working with universities or research laboratories because of their relatively unfettered, curiosity-driven research, while these laboratories may work with large firms because of their greater resources and commercial expertise. In all cases it is an attraction based on varied competencies, which are the result of very divergent organizations with different ways of working. Herein lies the paradox: the more attractive the partner in this sense, the greater the opportunities for miscommunication and misunderstanding because of the differences between the partners.

Partner Selection

As a result of these potential problems, partner selection is the most critical decision affecting the success of technological collaboration. There are advantages in selecting partners for long-term relationships. As many of the motives for technological collaboration reflect attempts to deal with complexity and uncertainty in novel and rapidly changing technologies, it is perhaps unsurprising that there are advantages in partnerships with long time horizons. In long-term relationships the problems inherent in the technological collaboration paradox may be overcome. There is greater opportunity for firms to exchange knowledge equitably. Managers and technologists in different companies can develop better working relationships, and knowledge is more easily and comprehensively transferred. If these advantages are to be obtained, selection of the partner should be made on the basis of the long-term attractiveness of the collaboration, as well as the intrinsic interest of the proposed project.

Partner selection should therefore, be a strategic decision. In many successful collaborations, negotiations over partner selection are undertaken by top management, but this is not always the case. Success also seems more likely when partners provide complementary technologies. Complementarity in expertise is frequently cited as a reason for the technological success of the collaborations that enabled partners to learn novel skills.

Technological collaborations facilitate the transfer of knowledge. Once this knowledge has been transferred, the need for the partnership may be assumed to be finished. As technologies and markets are continually developing, however, the transferred knowledge may no longer be the most appropriate for changed market conditions. Individual firms continue in their efforts to develop their specialist skills through R & D. For this reason there are advantages in firms collaborating not only on the basis of existing technology, but also on the understanding that partners may continue to improve their technological competencies. These improvements are related to the comparative advantages of individual firms.

Technologies may be completely complementary, but firms may have totally incompatible business aims. Collaborators will generally not want to compete in the same markets using the product of their partnership. Potential markets need to be demarcated, either on a product basis or geographically. Innovation and corporate strategies need to be sympathetic and mutually

supporting. Managers and technologists may find it difficult to work with people in similar positions in other firms with lower levels of competency. Specialist vocabulary may not be common, understanding of latest research techniques or findings may not be shared. Unequal competencies result in delays and diversion of efforts as the weaker partner is brought up to speed. Unless there is an element of respect for the partner's technological abilities, transfer is unlikely to be wholehearted. International collaboration accentuates the need for greater respect for partner competencies. Furthermore, awareness of the commensurate abilities of partners may provide a stimulus to creativity. It may, for example, provide an element of competitiveness between research teams, that assists innovation

Flexible and Adaptable structures

The process of technological collaboration is often described as tension ridden. In part these tensions derive from the way technologies and markets constantly change. Unless collaborations are dynamic, they may be aiming at a target that has moved. Throughout the course of a collaboration, opportunities may arise that were initially unforeseen, and outcomes from collaboration often may not be the ones originally envisaged. For these reasons, collaborations need to be adaptable in structure and purpose.
This case study of BT&D supports the view that collaboration should build longer term capabilities as well as focus on particular products, given that the latter may fail in the market or have limited life cycles. As the focus of collaboration may change over time—for example, as the project progresses nearer to the market—the skills mix of managers, scientists, and engineers needs to adapt accordingly.

Collaborative tension between BT and DuPont

When DuPont created a new technology venture with BT, called BT&D, the synergies appeared obvious. DuPont wanted to diversify out of chemicals into electronics, and BT had some excellent electronics technology in its research laboratory that it wanted to commercialize. However, within a short period tensions arose. Changing strategies of the partners. Increased prices for chemicals helped DuPont refocus priorities back into its traditional industry. BT shifted its strategy away from being a technology supplier towards becoming a service company.

Inexperience of one partner. DuPont had lengthy experience of joint venturing and working with small spin-offs. BT had very little and its expectations were too high as a result.

Reporting arrangements. The spin-off company reported to a technical function in BT and a marketing function in DuPont, and this caused some confusion.

Top management structure. It took some time to appoint an independent managing director for the joint venture, and until that time the representative of one partner company was viewed with suspicion by the other.

Cultural mismatch. One partner was essentially a research laboratory, with little market awareness; the other was a marketing organization, with little appreciation of the demands of R & D.

Harmonization of human resources. Staff on secondment to the joint venture from the partners had the salaries and conditions of the parent company. These differed and caused some tensions when it was discovered that people were being differentially rewarded for doing similar jobs.

Adjustment of the target market. The original business aim of the joint venture was not realized. DuPont pragmatically accepted this and allowed the joint venture to develop a new business. BT had problems with this.

Changing expectations. The joint venture became a very different company from that initially envisaged. DuPont accepted this, as it was commercially attractive. BT found the joint venture did not achieve what it wanted—that is, the commercialization of some of its technology. Originally the joint venture was owned 50-50. After a number of years DuPont bought a majority ownership. Eventually both founding partners sold their joint venture to Hewlett-Packard (HP) and it has now been merged into HP's massive spin-off, Agilent Technology.

Communications and Human-Resource Factors

Good communications within and between partners are critical to the success of technological collaboration. Building into partnerships effective communications paths is often problematic, particularly for small firms linking with multinationals. Having established the appropriate reporting linkages, the next problem is using them effectively. Reporting unnecessary or poor-quality information may reduce the credibility of the whole system (and the collaboration). Without giving away all the knowledge and skill that made one partner attractive to the other, it is important to transfer information that is necessary to make the collaboration work. Sometimes one partner may feel that it is contributing more than the other. In such circumstances, a quid pro quo is needed. This may be achieved at later stages in the project, or in future projects. It may be achieved formally, through, for example, proportional allocation of IPR or equity. Or it may be done informally through the trading or exchange of information at the discretion of project managers (using the so-called favour bank). Operating in periods when the flow of information is primarily one way requires a high level of trust in partners that the flow will in future be reversed. High-trust relationships within collaborations are often based on the assumption of continuity and reciprocity between partners. In-depth studies of technological collaboration place great emphasis on the personal factors that enable trust to develop and collaboration to succeed. Communications depend on individuals, and are enhanced by the ability of individuals to be trusted. Managers, scientists, and engineers are trusted by their equivalents in other firms to deliver what is expected of them, and on time. Counterparts are trusted to be honest, and not to impart false or misleading information. Trust is particularly important when there is imbalance in contributions to the collaboration. Partners may be trusted to rectify the imbalance in the future. As interpersonal trust between individuals in different organizations is likely to be affected by labour mobility or individual disagreements, successful technological collaboration often depends upon the extension of interpersonal trust to inter-organizational trust. This issue and broader considerations of trust are examined in greater detail later. The management of human resources provides the critical factor determining the success of partners within technological collaborations. Human-resource management is an important aspect of collaboration in a number of respects. First, collaboration requires very good project managers. Such personnel need to be

attracted into the partnerships, without, for example, jeopardizing career and pay prospects by working in what might be seen as a subsidiary activity. Second, given the importance of interpersonal communications in collaboration, the retention of key individuals—managers, scientists, and engineers—is crucial. Third, attention to human-resource issues can reduce the tensions that sometimes occur in collaborations because of the lack of harmonization between the salaries and conditions of partners.