Organizational and technological antecedents for knowledge acquisition and learning

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This paper examines the factors affecting the decision to acquire external technology and the relative importance of different technology acquisition strategies pursued by British and Japanese firms. The paper draws on a study of 38 firms, consisting of 23 UK-based and 15 Japanese firms. This is not a comparative study of British and Japanese technology acquisition strategies. Rather, we aim to identify common factors affecting the decision to acquire external technology and the means by which firms attempt to do this. We identify two clusters of variable which appear to affect the decision to acquire technology. Firstly, an organization's inheritance, which includes corporate strategy, competencies, culture and what we refer to as management's 'comfort' with the technology. Secondly, the characteristics of the technology to be acquired, specifically, its competitive impact, complexity, codifiability and what we refer to as 'credibility' potential. Together, these factors will determine the degree and nature of technology acquisition strategy. We find that contrary to the present academic preoccupation with alliances and joint ventures, the firms examined ranked universities, research consortia and licensing as the most important sources of external technology.

Rationale for technology acquisition

Firms choose to acquire technology from external sources rather than develop it in house for a number of reasons. Two theoretical models have dominated the issue of technology acquisition, namely transaction cost analysis and strategic behaviour (McGee and Dowling, 1994). Transaction cost analysis focuses on organizational efficiency, specifically where market transactions involve significant uncertainty. In such cases sellers of technology may engage in opportunistic behaviour (Eisenhardt, 1989). Generally, the fewer potential sources of technology, the lower the bargaining power of the purchaser, and the higher the transaction costs (Pisano, 1990). In addition, where the technology is complex it can be difficult to assess its performance. Therefore transaction costs are increased where a potential purchaser of technology has little knowledge of the technology (Teece, 1986, 1988). In this respect the acquisition of technology differs from subcontracting more routine tasks such as production or maintenance work (Hauschildt, 1992). This suggests that acquisition of technology will require a closer relationship between buyers and sellers than traditional market transactions (Haour, 1992), resulting in a range of possible acquisition strategies and mechanisms (Granstrand et al., 1992). For example, Welch and Nayak (1992) argue that the optimal technology acquisition strategy will depend on the maturity of the technology, the firms technological position relative to competitors and the strategic significance of the technology.

However, studies of technology licensing suggest that transaction cost considerations are not the most significant factors affecting
the decision to acquire external technology. Moreover, the cumulative effect of outsourcing various technologies on the basis of comparative transaction costs may limit future technological options and reduce competitiveness in the long term (Bettis et al., 1992). Atuahene-Gima (1992) identifies three clusters of variables which may explain the decision to acquire technology: the characteristics of the firm, including its absorptive capacity and development capability; the market for technology; and the characteristics and perceptions of management, including the perceived relative advantage and complexity of acquiring external technology. Strategic issues such as market expansion and extending product portfolios may also be important incentives (Atuahene-Gima and Patterson, 1993).

A strategic behaviour perspective focuses on organizational effectiveness, and recognizes that the minimization of transaction costs may not be the only or indeed the most important determinant in technology acquisition, but rather that the decision whether to acquire technology externally is driven by longer term competitive considerations. The early normative strategy literature emphasized the need for technology development to support corporate and business strategies (Porter, 1983), and therefore technology acquisition decisions began with an evaluation of company strengths and weaknesses (Harrison and Pelletier, 1993). The more recent resource-based approach emphasizes the process of resource accumulation or learning (Pfeffer and Salancik, 1978; Robins and Wiersema, 1995). Competency development will require firms to have an established intent to use technology acquisition as an opportunity to learn rather than minimise costs (Hamel, 1991). This suggests that the acquisition of external technology complements internal research and development, rather than being a substitute for it. There is some empirical evidence that the internal R&D function should be involved in the evaluation, transfer and improvement of external technology (Sen and Rubenstein, 1990). For example, a study of multi-technology companies found that a strategy of technology acquisition was associated with diversification into increasingly expensive new technologies (Granstrand et al., 1992).

In practice, neither transaction costs nor strategic behaviour fully explains actual behaviour, and to some extent the approaches are complementary (Tidd et al., 1997). For example, a study of the managerial and economic information considered by top executives in the evaluation of technological collaboration found that two of the most significant factors considered were the importance of the technology to current strategy and the potential for decreasing development risk (Tyler and Steensma, 1995). Thus both strategic and transaction cost factors appear to be significant. However, the study by Tyler and Steensma (1995) was based on a policy-capturing methodology whereby executives were presented with hypothetical scenarios and given a range of possible actions. Therefore the findings may not be representative of actual behaviour. Indeed, the authors themselves suggest that a grounded theoretical approach based on fieldwork might contribute a richness not possible in such a controlled experiment and may identify additional factors affecting decision making. Here we attempt to provide a richer conceptual framework in which to understand why and how research managers decide to acquire external technology, by examining the policy and practice of 38 firms.

**Sample and methodology**

A total of 38 firms were studied, representing a wide range of different sectors (Table 1). These consisted of 23 UK-based firms and 15 firms in Japan. Although a similar methodology was used for both the British and Japanese samples, resources did not allow the two samples to be matched by firm size or sector. The sample was non-random, and we make no claim that it is representative in terms of sector or firm size. Rather, we focused our efforts on those firms which claimed to utilize external sources of technology and to which we had good access via our academic and professional relations. As a result, the UK sample was biased towards large firms from process industries, and the Japanese sample biased towards large manufacturers of discrete products. Given the differences in the compositions of the
For each of the firms examined, the head of research and development was interviewed, and in some cases additional interviews were conducted where others were responsible for technology transfer and licensing. In total, some 50 interviews were conducted. For the interviews in Japan interpreters were available, but rarely needed because of the English language skills of most high-level research managers in Japan. In both cases a structured questionnaire was used to guide the interviews, and wherever possible the R&D managers were asked to provide specific examples of technology acquisition in addition to any explicit technology policy pursued by the firm. This approach allowed us to compare formal company policy on technology acquisition with the perceptions and practice of the managers interviewed. Most firms also provided documentary details of specific projects. However, care must be taken when interpreting these accounts, as we did not have the accounts of others involved in the various projects. The identity of the firms has been protected because some of the material was provided in confidence.

Factors driving technology acquisition

For all of the firms studies, in-house R&D (i.e. generated within either ‘central/corporate’ laboratories or ‘divisional’ R&D facilities) was the organization’s single most important source of technology. This is consistent with the sample bias towards larger firms: almost all of the firms had significant in-house technical resources, and in general external sources of know-how were regarded as complementary, rather than substitutes. Therefore despite the key role of in-house R&D, outside technology sources were increasingly being utilized. With only two exceptions, all firms questioned ranked externally generated technology as being ‘important’ in at least some of their technical activities. Even the two exceptions had tried, unsuccessfully, to access outside technical developments for a number of years. In one case the apparent failure to do so seemed to be a consequence of the highly specialized nature of this firm’s operations. In the other case, the firm had pursued a strategy of technological diversification and believed that its technologies formed the basis of product differentiation, and therefore too important to source externally. Nevertheless, more than half the companies studied believed that external technological developments will assume even greater importance over time. The most commonly cited reasons

Table 1. Sample of companies.

<table>
<thead>
<tr>
<th>Firm code</th>
<th>Primary business</th>
<th>Turnover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agri A</td>
<td>Agriculture</td>
<td>Large</td>
</tr>
<tr>
<td>Agri B</td>
<td>Agriculture</td>
<td>Large</td>
</tr>
<tr>
<td>Biotech A</td>
<td>Biotechnology</td>
<td>Small</td>
</tr>
<tr>
<td>Biotech B</td>
<td>Biotechnology</td>
<td>Small</td>
</tr>
<tr>
<td>Chem A</td>
<td>Chemicals</td>
<td>Large</td>
</tr>
<tr>
<td>Chem B</td>
<td>Chemicals</td>
<td>Large</td>
</tr>
<tr>
<td>Chem C</td>
<td>Chemicals</td>
<td>Large</td>
</tr>
<tr>
<td>Consumer A</td>
<td>Consumer products</td>
<td>Large</td>
</tr>
<tr>
<td>Consumer B</td>
<td>Consumer products</td>
<td>Large</td>
</tr>
<tr>
<td>Consumer C</td>
<td>Consumer products</td>
<td>Large</td>
</tr>
<tr>
<td>Energy A</td>
<td>Energy</td>
<td>Medium</td>
</tr>
<tr>
<td>Energy B</td>
<td>Natural Resources</td>
<td>Large</td>
</tr>
<tr>
<td>Energy C</td>
<td>Natural Resources</td>
<td>Medium</td>
</tr>
<tr>
<td>Oil A</td>
<td>Oil &amp; gas</td>
<td>Large</td>
</tr>
<tr>
<td>Oil B</td>
<td>Oil &amp; gas</td>
<td>Large</td>
</tr>
<tr>
<td>Oil C</td>
<td>Oil &amp; gas</td>
<td>Large</td>
</tr>
<tr>
<td>Oil D</td>
<td>Oil &amp; gas</td>
<td>Medium</td>
</tr>
<tr>
<td>Pharm A</td>
<td>Pharmaceuticals</td>
<td>Large</td>
</tr>
<tr>
<td>Pharm B</td>
<td>Pharmaceuticals</td>
<td>Large</td>
</tr>
<tr>
<td>Pharm C</td>
<td>Pharmaceuticals</td>
<td>Large</td>
</tr>
<tr>
<td>Research A</td>
<td>Contract Research</td>
<td>Medium</td>
</tr>
<tr>
<td>Research B</td>
<td>Contract Research</td>
<td>Small</td>
</tr>
<tr>
<td>Research C</td>
<td>Environmental</td>
<td>Small</td>
</tr>
<tr>
<td>Auto. A</td>
<td>Car manufacture</td>
<td>Large</td>
</tr>
<tr>
<td>Auto. B</td>
<td>Car components</td>
<td>Large</td>
</tr>
<tr>
<td>Auto. C</td>
<td>Car components</td>
<td>Large</td>
</tr>
<tr>
<td>Chem. D</td>
<td>Chemicals</td>
<td>Large</td>
</tr>
<tr>
<td>Chem. E</td>
<td>Chemicals</td>
<td>Large</td>
</tr>
<tr>
<td>Consumer D</td>
<td>Consumer products</td>
<td>Large</td>
</tr>
<tr>
<td>Electrical A</td>
<td>Consumer electronics</td>
<td>Large</td>
</tr>
<tr>
<td>Electrical B</td>
<td>Consumer electronics</td>
<td>Large</td>
</tr>
<tr>
<td>Mech. A</td>
<td>Mechanical engineering</td>
<td>Large</td>
</tr>
<tr>
<td>Mech. B</td>
<td>Mechanical engineering</td>
<td>Medium</td>
</tr>
<tr>
<td>Mech. C</td>
<td>Mechanical engineering</td>
<td>Medium</td>
</tr>
<tr>
<td>Mech. D</td>
<td>Mechanical engineering</td>
<td>Small</td>
</tr>
<tr>
<td>Mech. E</td>
<td>Mechanical engineering</td>
<td>Small</td>
</tr>
<tr>
<td>Research D</td>
<td>Research institute</td>
<td>Small</td>
</tr>
</tbody>
</table>

Large = >£1 billion turnover
Medium = >£100 million turnover
Small = <£100 million turnover

British and Japanese samples it was not possible to undertake any comparative analysis. Rather, we have pooled the observations where possible in order to identify common factors.

Knowledge acquisition and learning
for acquiring technology were constraints on resources, the increasing diversity of technology and the organizational benefits.

Resource constraints
In the current highly competitive business environment, which is forcing all areas of a company’s operations to achieve greater financial efficiencies, the R&D function was required to achieve ‘more with less’ and to examine critically whether in-house development was the most efficient approach. In addition, there is an increasing recognition that one company’s ‘peripheral’ technologies are usually another’s core activities, and that it often makes sense to source such technologies externally, rather than to incur the risks, costs and (most importantly of all) timescale associated with in-house development (Mansfield, 1988).

Technological diversity
The rate of technological change, together with the increasingly complex nature of many technologies, means that few organizations can now afford to maintain in-house expertise in every potentially relevant technical area (Granstrand et al., 1992). Almost all of the R&D managers believed that no company, however large, can continue to survive as a ‘technological island’. In addition, there is a greater appreciation of the important role that external technology sources can play in providing a ‘window’ on emerging or rapidly advancing areas of science (Ölifestyles and MacDonald, 1988). This was felt to be particularly true when developments arose from outside a company’s traditional areas of business, or from overseas.

Organizational benefits
There is a realization that access to outside technology sources can bring about other important organizational benefits, such as providing an element of ‘peer review’ for the internal R&D function, reducing the ‘Not-Invented-Here’ syndrome, and challenging in-house researchers with new ideas and different perspectives (Sen and Rubenstein, 1990). In addition, many managers realized the ‘tactical value’ of certain types of externally-developed technology. Some of these are increasingly viewed as a means of gaining the goodwill of customers or governments, of providing a ‘united front’ for the promotion of uniform industry-wide standards, and even as a ‘lever’ that can sometimes be used to influence future legislation.

Despite the widely recognized importance of ‘technology scouting’, however, such activities were almost always performed on an ad hoc basis. Only two of the firms examined had a director of technology acquisition, and outside the pharmaceutical industry, only three firms had groups specifically charged with technology scouting activities. Indeed, one firm has set up such groups in five different countries.

Technology acquisition strategies
In this section we examine the ways in which the firms in this study acquire technology, highlighting conditions under which each particular source and method is favoured. Company perceptions about the relative merits of each route are illustrated by representative examples drawn from the interviews. The sample bias does not allow us to draw robust conclusions regarding the relative popularity or frequency of different sources of technology. However, it is interesting to note that universities are considered to be the most important source of external technology, followed by research consortia, licensing and suppliers and customers (Table 2). In comparison, commercial research organizations, alliances and acquisitions are considered less significant sources of technology. This finding contrasts with the findings of previous research which has emphasized the importance of customers (von Hippel, 1987), suppliers (Nishiguchi, 1994) and alliances (Pisano, 1990) as sources of technology. This may be due to the sector-specific focus of much of the previous work, as suggested by Pavitt (1990), whereas our study represents a wide range of sectors. The wide range of sectors included in our study does allow us to identify some broad relationships between sector and sources of technology (Figure 1). Many of the projects we examined concerned the...
acquisition of scientific know-how, rather than the transfer or application of technologies, and therefore the role of universities, consortia and licensing may be overstated. Alternatively, the apparent differences in emphasis observed may represent a time-lag between the concerns of managers and academic research. We will examine each of the different sources of external technology in turn, and provide specific examples.

Universities
Our study suggests that universities are the most widely used external source of technology, all but one of the companies examined being actively involved in or funding a number of different types of university research projects. These relationships range from CASE studentships to support PhD candidates, extra mural research awards for post-doctoral staff to carry out research in a

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Table 2. Relative importance of external sources of technology

<table>
<thead>
<tr>
<th>Source of technology</th>
<th>Percentage of firms which consider source to be of major or moderate significance (n = 38)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Universities</td>
<td>79</td>
</tr>
<tr>
<td>Consortia</td>
<td>61</td>
</tr>
<tr>
<td>Licensing</td>
<td>34</td>
</tr>
<tr>
<td>Customers and suppliers</td>
<td>34</td>
</tr>
<tr>
<td>Company acquisition</td>
<td>16</td>
</tr>
<tr>
<td>Joint ventures and alliances</td>
<td>13</td>
</tr>
<tr>
<td>Commercial research organizations</td>
<td>5</td>
</tr>
</tbody>
</table>
specified area, to more formal contract research and collaborative schemes such as the LINK scheme jointly funded by the DTI and a number of companies to conduct pre-competitive research in a specified area. The companies interviewed in this study consistently highlighted three important roles of university-funded research in their technology acquisition strategies: to access specialist technical support; to extend in-house research; and to provide a window on emerging technologies.

Access to specialist facilities or non-core technical activities is a common reason for working with universities. For example, both Pharma A and Biotech B have funded research at universities to gain access to specialist equipment or techniques — either as a ‘one-off’ exercise, or to allow them to make an informed judgement about whether to acquire such equipment themselves. Agri A made extensive use of universities to undertake fundamental studies into the molecular biology of plants and the cloning of genes. Although not key technologies, access to ‘state-of-the-art’ knowledge in these areas is vital to support a number of the organization’s core agricultural activities. Extensions to existing in-house research typically involved using universities to conduct either fundamental research (i.e. research aimed at gaining a better understanding of an underlying area of science), or more speculative extensions to existing in-house programmes (which could not be justified internally because of their high risk, or because of limited in-house resources). For example, Research A utilized technology originally developed at Edinburgh and Cambridge universities in its optical and sensor products. Similarly, Research B used this route to gain a better understanding of the factors affecting battery lifetimes. Virtually all firms surveyed highlighted the important role of universities as windows on emerging or rapidly advancing fields of science and technology. Companies viewed access to such information as being critical in making good decisions about when (or whether) to internalise a new technology. Indeed many organizations provided general research funding to leading professors, specifically to retain access to this ‘window opening’ function. For example, Chemical A launched a series of university-funded research programmes in the US during the late 1980s. During its first 3 years, these programmes yielded 40 patent applications.

There was general agreement that universities should be used to ‘do what they’re best at’, that is speculative or fundamental research, and that they were not good places in which to develop products that needed to reach the market quickly (McHenry, 1990). Despite this widely held view, many companies felt it was still important to agree clearly-defined milestones at the outset of a project, and to measure progress against these at pre-determined intervals. The major area of concern with university research appeared to be over the IPR issue (Burrington, 1993). More than half the companies interviewed felt that universities often had unrealistic expectations of the value of their work, specifically they did not appreciate the costs and risks of scaling-up and marketing technology that looked promising in the lab. As a consequence, many universities were thought to demand excessive royalties. Other companies criticized universities’ demands to retain the IPRs to their work. The concern here was not normally about universities wishing to receive fair recompense for their work, but with the fact that enforcing IPRs world wide was not normally one of a university’s core competencies. Some companies, to whom exclusivity is of over-riding importance, make it a pre-condition of all their university contracts that the company either retains the IPR to any discoveries, or else that it has first refusal of exclusive commercialization rights.

Research consortia

The majority of companies interviewed were, or had recently been, involved in research consortia. However, compared to bilateral alliances, there has been relatively little research on the arguments for and effectiveness of consortia (Souder, 1993). Consortia, defined as multi-firm collaborations, take two main forms, between competitors or between non-competing firms (Rhea, 1991).

Slightly more than half the firms questioned collaborated with competitors in ‘pre-competitive’ technologies, i.e. ‘window-opening’ activities, in areas of science still
far away from commercial exploitation. This method was seen as being particularly attractive when collaborative efforts were also supported by government or EC funds, and in most cases was modelled on an understanding of Japanese consortia (Tidd and Brocklehurst, 1991; Hane, 1994). However, some companies felt that concerns with protecting underlying competitive positions led to difficulties in identifying realistic problems that could be shared in such consortia, and that this significantly reduced the value of these initiatives. In practice, intra-industry collaborations appeared to be more important in ‘non-competitive’ technologies, such as in the areas of health, safety, and the environment (where everyone clearly benefits), and in setting new standards or influencing legislation (where it is important for the industry to present a ‘united front’). For example, Electrical B participated in a consortium of electronics and telephone firms to develop standards for digital cell phones and pagers, but the subsequent development of the equipment was by means of a number of bilateral codevelopment projects between NTT and various manufacturers of consumer electronics. Similarly, the 1990 US Clean Air Act placed the onus on automobile manufacturers and oil companies to provide the basic science which will act as a realistic foundation for future legislation. Competing oil companies and auto manufacturers set up the Auto-oil consortium to provide this science. In such cases Auto B favoured codevelopment via research consortia, rather than exclusive joint venture arrangements.

By contrast, in industries where less value is placed on keeping technology proprietary (e.g. oil exploration and production) intra-industry collaboration, even in ‘exploitable’ technologies, appeared commonplace. Indeed, both Oil A and Oil C highlighted that it was a firm’s ability to make best use of a technology, rather than its generation per se, that gave them a competitive advantage. Both firms appeared, independently, to have coined the phrase ‘co-operate to compete’. For example, oil companies in both the US and Europe have set up a series of fora at which their representatives meet regularly to discuss potential collaborative research projects. To date, over 200 joint R&D projects have been, or currently are being, undertaken. In contrast to the above, these are not in ‘pre-competitive’ areas; such projects aim to develop technology that can immediately be commercially applied by all participants.

Collaboration between firms in different industries appeared to raise much less concern about proprietary positions, perhaps because the British firms appeared to adopt a defensive approach to participation in consortia. In most cases, they were viewed as an attractive means of leveraging in-house skills by working with organizations possessing complementary technical capabilities, rather than as a means to acquiring know-how or learning. This seemed especially true in areas where technology fusion was thought to be possible. As a result, this type of collaboration appeared particularly popular, with over 80% of companies questioned claiming to utilize this route. Nevertheless, even in consortia involving non-competing firms, it appears that vested interests can sometimes lead to difficulties. For example, in the collaboration between auto-manufacturers and oil companies aimed at reducing toxic emissions from car exhausts, Oil D highlighted the serious differences of opinion between these two groups of firms about whether the main thrust of the research should be directed towards improved engine efficiencies, or towards better gasoline formulations.

Licensing

Licensing appeared to be among the most widely used methods for acquiring technology, with around a third of the companies interviewed claiming to licence-in external technology. This level of licensing is consistent with surveys of US firms (Contractor, 1983). The main attraction is that it enables firms rapidly to establish positions in new technical areas, particularly in those which complement existing core skills. For example, Pharma A licensed-in basic cephalosporin technology originally developed at a UK university, and used its in-house skills to produce a wide range of these antibiotics, hence adding value to the licensed technology. Similarly, Research C looked to acquire and adapt relevant complementary technologies that could be ‘bolted on’ to its core products (based monoclonal...
antibodies that detect environmental contaminants). Often these developments come from related sectors, such as the medical diagnostics industry. The company believes that obtaining exclusive licenses for complementary technology from non-competing firms is just as effective as proprietary IPR in providing it with a source of competitive advantage.

In the majority of firms which choose not to license-in technology, however, the reluctance seemed to be related to concerns about maintaining the differentiation of products or services if customers became aware that these were based on licensed-in (and, by inference, ‘commodity’) technologies. Chemical B pointed to increasing globalization and concentration within its industry as reducing the scope for licensing technology. Chemical E expressed similar concerns regarding the constraints imposed by international licensing agreements, specifically the common requirement to ‘grant-back’ any improvements made to the technology. For these reasons a number of the Japanese firms were very careful to license only components of any process or product in order to allow scope for subsequent improvement and differentiation. For example, Chemical E had licensed a well-established process technology from a US competitor, but chose not to license the catalyst or polymer design. This allowed the company to avoid having to grant-back its subsequent improvements to the catalyst and polymer design to the American competitor. Auto B had adopted a similar strategy when licensing technology from potential competitors. However, this approach is only viable where the technology can be easily ‘unbundled’. For example, Consumer D found that in most cases it was able to negotiate and exploit simple licenses for its brewery and food businesses, but not for its pharmaceutical products. The company preferred formal joint ventures to develop new pharmaceutical products because of the complex inter-related technologies, patents and skills required.

**Customers and suppliers**

Around a third of the firms interviewed had collaborated with customers to develop technology. The main motives for this were either to gain credibility for their products (in the eyes of the customer), or jointly to develop technology that could subsequently be used to satisfy other customers, or to gain market share (i.e. to ‘establish a position’). For example, Energy A had made a strategic decision to co-operate with foreign customers, and to source technology from countries in which it wishes to sell its products and technology. It sees such collaborations as an important factor in gaining the goodwill of both potential customers and national governments (who exert a major influence over most of this organization’s customers). Similarly, Oil B conducts a large amount of collaborative research with important customers in technical areas of mutual interest. Not only does this leverage its in-house R&D capabilities, but it also provides the firm’s products with credibility in the eyes of these customers.

Some firms, notably those with interests in oil exploration/production and specialty chemicals, appeared to make extensive use of technical collaborations with their suppliers. In the former case, this seemed to be facilitated by the structure of the upstream oil industry. In the latter area, the size, and scientific competence, of many suppliers to the specialty chemicals industry appeared to be the main driving force for such collaborations. Oil A claimed that one of the main purposes of its own R&D expenditure is to ‘force the pace’ at which its suppliers innovate. It is therefore prepared to work with these firms to develop new technology and (in exchange for favourable terms) to allow these suppliers to use the jointly-developed technology when working with other oil companies.

**Equity and company acquisition**

In recent years, roughly half the organizations in this study had purchased stakes in other firms (normally small entrepreneurial companies) to provide a means of accessing a new technology. Normally, the rationale behind this was to establish a position quickly in that particular technical area (Link, 1988). However, feelings about the effectiveness of this route were mixed; most acquisitions appeared to have suffered from the loss or demotivation of key staff, or had...
failed to realize their expected potential for other reasons (Hull and Slowinski, 1990). In the light of these disappointments, take-overs seemed to have become less popular as a means of accessing technology. Nevertheless, a few companies claimed spectacular successes among their acquisitions. The common factors here appeared to be prior experience of the markets in which the new technology would be used, and a ‘compatible’ culture between the two organizations. For example, as part of Pharma A’s ongoing activities in anti-cancer drugs, it identified a small US company working on an enzyme believed to be a catalyst in tumour growth. The company considered this technology sufficiently promising to invest $4.5 million in acquiring an 8% stake in the company and ‘first claims’ to any resulting drugs. Similarly, Pharma C identified the potential fit of a technique called ‘oximetry’ with its medical equipment business, and purchased the firm that had invented the method. Such was the success in exploiting this technology that the pay-back period for the acquisition was less than 6 months, and ‘oximeters’ have now become commonplace throughout the medical industry.

Joint ventures and alliances

Despite the present interest which academics have in alliances and joint ventures (e.g. Bidault and Cummings, 1994; Hagedoorn and Schakenraad, 1994), these routes were used by a minority of companies studied. The largest joint venture identified in this survey involved companies Oil A and Oil C who, along with a number of other oil and computer firms, have jointly formed the Petrotechnical Open Software Corporation (POSC) to establish industry-wide database and computing standards. POSC standards now allow oil companies to purchase compatible software ‘off the shelf’, and the partners highlight the substantial cost-savings this makes, since modifications to the complex programs and databases used in petroleum exploration and production often cost 2–3 times that of the original software.

Many of the Japanese firms examined preferred codevelopment or cross-licensing to formal alliances or joint venture agreements. For example, Consumer D exchanged the genes it had developed for chilling resistance and carotenoid bio-synthesis for the antisense polygalactunase gene (‘FLAVSAVR’) developed by Calgene in the US. Each company would attempt to exploit the others technology in new applications. This type of technology exchange programme combines some of the benefits of joint ventures, such as exploiting complementary assets, without some of the major drawbacks, such as culture conflicts and leakage of other commercially sensitive know-how (Dickson et al., 1991).

Contract research

Views about UK public sector organizations and commercial contract research laboratories varied. Some were seen as useful but others were claimed to have over-sold their capabilities, which has led to disappointment. In general, contract research was seen as being most important when a company was interested in using the technology to ‘create options’. Some companies pointed to the credibility that using well respected contract research organizations can provide (e.g. in the eyes of foreign governments). For example, Oil A had used the explosion test facilities at the Christian Michelson Institute (Norway) to model gas explosions. The motives for this were both to share costs in developing a non-competitive technology and to ‘court favour’ with the Norwegian Government, which views offshore safety R&D as a priority.

Intra-company transfer

In addition to the more obvious sources of external technology already reviewed, managers highlighted the changing balance between three potential sources of internally generated technology, specifically the respective role of internal venture groups, corporate research laboratories, and divisional R&D facilities. Internal venture groups were popular throughout the 1970s and 1980s, but less so in the 1990s. Recent research has identified a range of factors which have contributed to their decline (Garud and Van de Ven, 1992). Thus the main issue facing firms today is the share of resources of the central or corporate laboratories, which are normally large, multidisciplinary research establishments, with at
least an element of corporate funding, and the divisional or business unit R&D facilities, which are funded by, and support one particular business (Roussel et al., 1991).

Our study confirms the dramatic decline in the use of internal venture groups as sources of new technology. Although a number of companies had set up such groups in the past, none claimed that this route was currently an important component of their technology acquisition strategy. Similarly, many managers reported the declining importance of the central corporate R&D laboratories in favour of greater emphasis on research at divisional or business level. The latter are usually smaller and more specialized than corporate research laboratories. Where a company has both types of R&D laboratories, there was general agreement that technology which could be applied across a range of business units, R&D requiring multi-disciplinary inputs, and window-opening or breakthrough research, particularly when this was longer term in nature, were best performed at the central location. By contrast, technology concerned with ‘establishing a position’, making incremental extensions to existing products and processes, or with providing technical support to one specific business unit, was better performed within a divisional R&D facility.

In this context, it is notable that several of the organizations interviewed, particularly those from the Oil and Chemical industries, had recently, or were in the process of, placing increasing emphasis on divisional R&D facilities at the expense of central research laboratories. The main driving forces behind this seemed to be to improve the responsiveness of R&D to the needs of the business units and their customers and to increasing the accountability of the R&D function for technology delivery. However, this increasing focus on the needs of existing businesses and product-markets may reduce the potential to exploit technological synergies across businesses, and in the longer term may prevent the emergence of new businesses based on novel technologies (Tidd, 1993, 1995). Therefore there may be a role for central research facilities and internal venture groups after all.

Factors affecting choice of acquisition strategies

Throughout this study, two broad issues were observed to dominate companies’ attitudes toward technology acquisition. One was related to the organization’s ‘inheritance’ factors, which include the company’s strategy and existing technical capabilities, as well as ‘softer’ factors such as the firm’s culture and the ‘comfort’ of its management with a given technical area. This term encompasses company characteristics which, at least in the short-run, are fixed and therefore represent constraints within which the R&D function develops its strategies for acquiring technology. The other set of factors concerned the characteristics of the technology in question, including its competitive impact, complexity, codifiability and credibility potential (Table 3). Together, these factors appear to determine the acquisition strategy of firms.

Corporate strategy

One important factor affecting the balance between in-house generated, and externally acquired, technology is the degree to which company strategy dictates that it should pursue a policy of technological differentiation or leadership. For example, Consumer A recognized two types of technical core competencies; ‘strategic’ i.e. those activities in which the company must be a world leader because they represent such an important source of competitive advantage), and ‘enabling’ i.e. skills required for success, but which do not have to be controlled internally. Although all strategic activities were retained in-house, the company is prepared to access enabling pieces of science externally, if the overall technology was sufficiently complex that it would not be practical to hold all the necessary skills internally. Research A was one of the first UK laboratories to transform successfully from a corporate R&D centre, to a specialist ‘one-stop innovations shop’ providing external clients with specialist products, licensing and R&D services. With one recent Nobel Prize winner, and royalty income alone currently running at 2.5 times total running costs, this organization is genuinely and demonstrably a self-sufficient
Knowledge acquisition and learning

Table 3. Links between technology acquisition strategy, organizational factors and characteristics of technology

<table>
<thead>
<tr>
<th>Organizational factors</th>
<th>Technological factors</th>
<th>Acquisition mechanism</th>
<th>Most favoured/alternative</th>
<th>Rationale for decision</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Comfort with new technology</td>
<td>In-house corporate/university</td>
<td>In-house R&amp;D/equity acquisition</td>
<td>Differentiation, first mover, proprietary technology</td>
</tr>
<tr>
<td></td>
<td>Competitive importance of technology</td>
<td>License/contract/customers and suppliers/consortia</td>
<td>License/contract/customers and suppliers/consortia</td>
<td>Cost effective/secure source</td>
</tr>
<tr>
<td></td>
<td>Complexity</td>
<td>In-house R&amp;D/joint venture</td>
<td>In-house corporate/university</td>
<td>Cost effective/secure source</td>
</tr>
<tr>
<td></td>
<td>Codification</td>
<td>University</td>
<td>In-house R&amp;D/joint venture</td>
<td>Cost effective/secure source</td>
</tr>
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<td></td>
<td>Credibility potential</td>
<td>In-house corporate/university</td>
<td>In-house R&amp;D/equity acquisition</td>
<td>Differentiation, first mover, proprietary technology</td>
</tr>
</tbody>
</table>

generator of technology. The company explicitly aims to be the world leader in every one of its core technologies; if this cannot be achieved, its strategy is not to pursue that technology any further.

Firm competencies

An organization’s internal technical capabilities are another factor influencing the way in which it decides to acquire a given technology (Lei and Slocum, 1992). Where these are weak, a firm normally has little choice but to acquire from outside (at least in the short-run), whereas strong in-house capabilities often favour the internal development of related technologies, because of the greater degree of control afforded by this route. In such cases, the main driving force behind the ‘make or buy’ decision is speed to market. For example, speed to market is a critical success factor for the four Consumer firms. These firms select the technology acquisition method that provides the fastest means of commercialization. When the required expertise is available in-house, this route is normally favoured because it allows greater control of the development process, and is therefore usually quicker. However, where suitable in-house capabilities are lacking, external sourcing is almost always faster than building the required skills internally. In the case of Consumer B, for example, one of its new products required laser spot-welding competencies that the company lacked, so it was forced to go outside to acquire this technology. Other companies sought to access external sources of technology to ‘fill gaps’ in their in-house competencies, or to provide an ‘informed buyer capability’ when such expertise is not available internally.

Company culture

Every company has its own culture, and these underlying values and beliefs play an
important role in technology acquisition policies. A few firms felt that, in the past, a culture of ‘we are the best in our key technologies’ may have contributed toward their rather myopic view of external technology developments. Other organizations, however, consistently reinforced the philosophy that important technical developments could occur almost anywhere in the world. Consequently, staff in these companies generally made great efforts to locate ‘pockets of innovation’, and to internalize potentially important developments, before the competition. For example, Pharma B viewed the current explosion of knowledge as providing an ever increasing range of scientific possibilities. It repeatedly emphasized that companies need to guard against becoming captives of their own in-house expertise, since this limits the scope of their activities to what can be achieved through their own resources. This organization emphasized that, although relevant sources of new ideas may shift and vary, it was essential to find ways of tapping these if a company is to remain at the sharp end of innovation. With this in mind, the company has expanded its research effort by placing many of its R&D locations overseas. This, it claimed, allows its research to benefit from different cultural and scientific approaches, and from being brought into intimate contact with the many different markets it serves. Local ‘champions’ from around the world are closely networked so that technical advances made in one geographic location are rapidly disseminated around the organization as a whole.

Management comfort

The fourth aspect of a company’s inheritance factors that appears to play a major role in the technology acquisition decision making process is related to the degree of ‘comfort’ its management has with a given technology. In some ways this is similar to company culture, but it manifests itself at the level of the individual R&D manager or management team, rather than at the level of the organization as a whole (McDonough and Barczal, 1991). Management comfort is multifaceted. One aspect of this appears to be related to a management team’s familiarity with the technology. Another may reflect their degree of confidence that the organization can succeed in a new technical area, perhaps because of a research group’s track record of success in related fields. Attitudes to risk is another facet of management comfort (Tyler and Steensma, 1995). Previous studies have suggested that the perceived relative advantage and complexity of technology acquisition may affect the decision whether to acquire technology (Atuahene-Gima, 1992), which to some extent is based on prior experience. Anecdotal stories suggest that a lack of management comfort with outside R&D sources may have inhibited some companies from making full use of external developments. However, here we are not concerned only with management’s ‘comfort’ with the process of technology acquisition, but also comfort and experience with specific types of technology.

All else being equal, the more comfortable a company’s managers feel with a given technology, the more likely that technology is to be developed in-house. For example, the current business of Agri. A was built on the basis of providing an outlet for the parent organization’s in-house biotechnology expertise. This means that the concept of world-leading in-house technology sits very comfortably with the organization’s top management, which is reflected by the fact that annual in-house R&D expenditure exceeds the firm’s annual capital expenditure by a considerable margin. Similarly, Research B’s core technologies of plant life extension, environmental sciences, modelling and land remediation treatment all derive from its nuclear industry background. Top management’s comfort with these technologies has led them to encourage staff to build on these skills, and to use these as a ‘springboard’ for diversification into new (in-house) scientific areas.

Competitive impact

Without doubt, the competitive impact of the technology was the single most important factor influencing companies’ decisions about how best to acquire a given technology (Roussel et al., 1991). Virtually all firms questioned during this study aimed to retain ‘key’ technologies, i.e. those providing
distinctive sources of competitive advantage, in-house. For example, Energy B and Chemical B view the unique technology embodied in their products as offering their customers a major source of competitive advantage. The competitive importance of technology to these companies leads them to place a greater reliance on in-house developed technology than do many of their competitors.

Strategies for acquiring ‘pacing’ technologies, i.e. those with the potential to become tomorrow’s key technologies, varied between companies. For example, some organizations, such as Research B, sought to develop and maintain at least some in-house expertise in many pacing technologies, so they will not be ‘wrong-footed’ if conditions change or unexpected advances occur. Other firms, such as Consumer A, also recognized the need to monitor developments in a number of pacing technologies, but see universities or joint ventures as the most efficient means of achieving this. The company sponsors a large amount of research in leading universities throughout the world, and has also set up a number of joint venture programmes with firms in complementary industries.

Most companies look to acquire ‘base’ technologies externally or, in the case of ‘non-competitive’ technologies, by co-operative efforts. Companies recognize that their base technologies are often the core competencies of other firms. In such cases, the policy of these companies is to acquire specific pieces of base technology from these firms, who can almost always provide better technology, at less cost, than could have been obtained from in-house sources. Technologies such as materials testing, routine analysis, and computing services were often quoted as examples of those that are now acquired externally.

**Complexity of the technology**

The increasingly inter-disciplinary nature of many of today’s technologies and products means that, in many technical fields, it is not practical for any firm to maintain all necessary skills in-house — even core activities. This increased complexity is leading many organizations conclude that, in order to stay at the forefront of their key technologies, they must somehow leverage their in-house competencies with those available externally. For example, the need to acquire external technologies appears to increase as the number of component technologies increases (Granstrand and Sjolander, 1990; Granstrand et al., 1992). In extreme cases of complexity networks of specialist developers may emerge which serve companies which specialize in systems integration and customization for end users (Miller et al., 1995).

For example, Agri A’s core skills centre around genetic engineering/molecular biology (allowing new characteristics to be inserted into plants), cell biology (enabling the regeneration of plants), and rapid screening/testing techniques for plants and seeds. These key technologies have been developed, and are retained, internally. Such is their complexity, however, that the company seeks to leverage these proprietary skills with complementary technologies accessed from other sources. Examples include techniques based on genetic fingerprinting (to speed up plant breeding, by enabling desirable characteristics to be identified without having to grow the plant to maturity) and the use of ‘anti-sense’ technology to isolate and clone agronomically important genes. Likewise, Research C maintains its core technical activities (developing and producing monoclonal antibodies) in-house but actively looks outside to acquire related technologies, that can be ‘bolted on’ to its existing products. These include kit design, dipsticks and measurement systems, and are often sourced from non-competing industries such as medical diagnostics. It expects its source of competitive advantage to shift gradually towards these features, as monoclonal antibody technology matures.

**Codification of the technology**

The more that knowledge about a particular technology can be codified, i.e. described in terms of formulae, ‘blueprints’ and rules, the easier it is to transfer, and the more speedily and extensively such technologies can be diffused. Knowledge that cannot easily be codified, often termed ‘tacit’ (Polanyi, 1966) is, by contrast, much more difficult to acquire, since it can only be transferred
effectively by ‘face-to-face’ interactions. All else being equal, it appears preferable to develop ‘difficult-to-codify’ technologies (often termed ‘black arts’) in-house. In the absence of strong IPR or patent protection, tacit technologies were recognized to provide a more durable source of competitive advantage than those which could easily be codified.

For example, Consumer A maintains all of its ‘strategic’ technologies in-house, even if these are considered mature, because of the large amount of tacit know-how embodied in even these technologies. The existence of ‘difficult-to-codify’ knowledge is one of the factors that has allowed this firm to maintain a competitive advantage in one particular core technology, even though the basic features of this technology have been in use for over a hundred years. Other companies also highlight the value of tacit knowledge by pointing to the difficulties in protecting IPR, given the increasingly sophisticated reverse-engineering tools now available, and the high levels of spending that a company’s global competitors can, collectively, devote to ‘breaking’ an important patent.

The appropriability of a technology is the extent to which the company that first discovers or develops the technology is able to capture the benefits arising from it. All else being equal, this study suggests that ‘highly appropriable’ technologies tend to be maintained in-house, whilst those that are difficult to appropriate are often developed within intra-industry research consortia, or by similar bodies such as trade associations. Many companies go to great lengths to ensure they can appropriate the ‘outcomes’ of their key technologies. For example, in the Pharmaceutical, Chemical and Research companies the importance they place on protecting their IPR have now assumed the status of core competencies within these organizations. In the case of Research A a third of its overheads are spent in this area. Indeed, the company claims its reputation for providing and enforcing IPR leads to approaches from many inventors and that this, in turn, provides the organization with new options for acquiring technology. Others companies, however, see their in-house developments as having limited appropriability, and therefore being less important as sources of competitive advantage. Not surprisingly, these companies were more comfortable with the thought of acquiring important technologies from external sources, collaborating with competitors, and of allowing their own in-house developments to diffuse around the industry. For example, because of the structure of the upstream oil industry, where most operations are performed by sub-contractors, known as service companies, new technical developments diffuse around the industry so rapidly that it is virtually impossible for technology to be a source of competitive advantage. Therefore two of the Oil companies actively encouraged collaborative R&D efforts, even in important technical areas.

Credibility potential

The credibility given to the company by a technology, or by the source of the technology, was found to be a significant factor influencing the way companies decide to acquire a technology. Particular value seems to be placed on gaining credibility or goodwill from governments, customers, market analysts, and even from the company’s own top management, academic institutions, and potential recruits. For example, Electrical B worked closely with the national telephone services provider although it had the depth and range of technologies required to develop telephony equipment and products. The rationale for the relationship was to influence future standards and to increase the credibility of its consumer telephone products in a market in which it was increasingly difficult to differentiate by means of product or service. Research D was engaged in a number of research projects with prestigious academic and commercial research institutions worldwide. In addition to gaining access to the technology, these relationships increased the credibility of the relatively young research institute with its partners and its parent company. Similarly Biotech. A’s collaboration with a large US chemical firm appears to have enhanced the former’s market credibility. Not only did the collaboration demonstrate this organization’s ability to manage a multi-million dollar R&D project (to the satisfaction of a much larger partner), but the numerous patents and academic publications that arose from it were
also felt to have improved the company’s scientific standing.

Implications for technology management

The practice of technology acquisition can be characterized by two polar extremes. On the one hand, a tactical view of external technology, which emphasizes the relative cost of ‘making versus’ buying a technology. On the other hand, a strategic view which sees the acquisition of external technology as a means to diversify into new product markets. Neither view is superior, but firms should have clear objectives for every specific case. However, it is clear from our study that whatever the formal policy of an organization may be, few firms have explicit criteria on which to base their technology acquisition decisions. Table 3 is our attempt to make explicit the links between the rationale for technology acquisition, different external sources of technology and the organizational and technological contingencies which appear to influence these.

Conclusions and further work

Our work suggests that two broad sets of issues appear consistently to exert most influence on companies’ decisions about whether to ‘make’, or to ‘buy’ a given technology: an organization’s ‘inheritance’ factors and the characteristics of the technology. The inheritance factors include the corporate strategy, technological competencies, company culture toward external sources, and managements comfort with new technology. The technological factors include the competitive impact of the technology, its complexity, codifiability and appropriability potential. These factors are illustrated schematically in Table 3, together with the most common acquisition mechanisms and rationale for the decision. For a specific firm, the organizational factors are for all practical purposes given, whereas the nature of the technology will vary with different projects.

There is broad agreement between our findings and previous research concerning the factors affecting the decision to acquire external technology, but some differences in emphasis. Our work confirms the relevance of technology characteristics such as complexity, codifiability and appropriability on sourcing decisions, but we also identify the tactical value of technology acquisition, specifically the potential to generate ‘credibility’ and goodwill with governments and customers. Much the same can also be said about the influence exerted by an organization’s inheritance factors. Inheritance factors represent constraints, arising from a company’s ‘history’, under which managers must operate. These cannot normally be altered, at least in the short-run. Our work confirms that corporate strategy and technical competencies influence companies’ technology acquisition decisions. However, we also identify what we refer to as managements ‘comfort’ with a particular technology or potential source of technology. This comfort factor appears to be a composite of corporate culture, familiarity with the technology and attitude to risk. Clearly further inter-disciplinary research will be required to determine whether this concept is sufficiently robust to explain behaviour.

Our findings are broadly consistent with much of the literature relating to the types of technology acquisition strategies used by firms. In particular, our work confirms the widely held view that in-house R&D is still the single most important source of technology, at least within large companies, but also supports claims that externally developed technology is becoming increasingly important to many organizations. The main divergence with previous work is the relative importance attached to different sources of technology. Our study suggests that universities, research consortia and licensing are the most common source of external technology, whereas the recent management literature has emphasized the role of suppliers, customers and strategic alliances. We believe that the reason for this is a fundamental shift in the rationale for technology acquisition. In the past the primary purpose of technology acquisition strategies were to acquire what was essentially tacit knowledge of technology of relatively low complexity, for example, component development in mechanical engineering industries or process development in...
the chemical industry. However, increasingly firms are seeking external sources of more complex, but more easily codifiable technology (Tidd, 1997). For example, the acquisition of computing hardware and software in the mechanical engineering sector, and the acquisition of biotechnology expertise in the chemical, pharmaceutical and food industries. Therefore within our framework we would expect universities, consortia and licensing to become more important acquisition mechanisms.

This raises the issue of the acquisition of know-how versus learning. There are three distinct components of organizational learning: knowledge acquisition; information distribution; and organizational memory (Huber, 1996). In this paper we have focused only on the first of these. However, the subsequent distribution and storage of externally-acquired knowledge are equally important, and warrants further study. Information distribution is the process by which information from different sources is shared and therefore leads to new knowledge or understanding. Greater organizational learning occurs when more of an organization’s components obtain new knowledge and recognize it as of potential use. The speed and extent to which knowledge is shared between members of an organization is likely to be a function of how codified the knowledge is (Boisot et al., 1996). Many firms now have databases and groupware to help store, retrieve and share information, but such systems are often confined to ‘hard’ data.Tacit knowledge is not so easily encoded, and therefore may not be fully visible to all members of an organization (Hendry, 1996). As a result organizational units with potentially synergistic information may not be aware of where such information could be applied.

Nonaka and Takeuchi (1995) argue that the conversion of tacit to explicit knowledge is the critical mechanism underlying the link between individual and organizational learning. They believe that all new knowledge originates with an individual, but that through a process of dialogue, discussion, experience sharing and observation such knowledge is amplified at the group and organizational levels. This creates an expanding community of interaction, or ‘knowledge network’, which crosses intra- and inter-organizational levels and boundaries. These knowledge networks are very different to the concept of the virtual corporation, in which a firm exploits the knowledge of its suppliers, customer and competitors. In contrast, knowledge networks are a means to accumulate knowledge from outside the organization, share it widely within the organization, and store it for future use (Brown and Duguid, 1996). In our future research we plan to examine how external know-how is most effectively internalized and translated into organization-wide learning.

References


Knowledge aquisition and learning


