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R&D Collaboration by 'stand-alone' SMEs: opportunities and limitations in the ICT sector

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Abstract

This paper focuses on SMEs for whom ICTs are a central, core technology. I argue that globalisation has profoundly affected the way in which SMEs organise their R&D activities. On the one hand, SMEs have always sought to specialise in niches, given their limited resources. As such, their role as specialised suppliers to large firms has increased. On the other hand, the cross-fertilisation of technologies has meant that they also need to span several competences. This state of affairs has altered the raison d'être of the SME.

The state of affairs vis-à-vis SMEs are discussed by examining two important concurrent dynamics. The first dynamic pertains to the various types of SMEs and how the industrial structure and external environment influences their collaborative activity. The second dynamic is associated with the evolution of technologies, technological paradigms and trajectories. I explain how different types of SMEs tend to predominate the industry structure at a given stage of the evolution of a given core technology. Evidence is presented from a survey on the collaborative activities of one particular form of the SME - the 'stand-alone' SME - in the ICT sector. The analysis is based on in-depth interviews and questionnaire surveys of over a 100 European technology firms and attempts to explain the reasons for the preference of one type of collaboration over another, and the limitations of collaboration as an alternative to in-house R&D.

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1. Introduction

The closing decades of the last century has seen fundamental changes in economic realities, often referred to as the process of globalisation. In particular, there has been an increasing enforceability of cross-border agreements (due in part to growing d*e facto* and *de jure* regional and global economic integration), a convergence in technological trajectories across countries, and an increased cross-border competition. In the context of this paper these developments have changed the way firms organise their innovative activity both spatially and organisationally. There is also an increasing international aspect of R&D activity, and a growth in the use of collaborative R&D between firms, both within and across borders.

From a technology perspective, there has been a growing knowledge content of products and processes, such that an increasing breadth of technologies is required. Automobiles have more computing power than the most desktop computers. Fridges are nowadays internet-enabled. And so on. This is associated with the pervasive role of information and computing technologies on sectors other than purely ICT products, sometimes referred as a cross-fertilisation of technologies. In this paper I shall focus on firms for whom ICTs are a central, core technology.

The need for multiple technological competences is partly responsible for the need for higher R&D resources. One response to the growing breadth of knowledge requirements has been to utilise non-internal means to undertake innovation, and by this I refer specifically to the use of strategic alliances and outsourcing. The developments have led to a prominent use of external resources belonging to non-affiliated firms as a way to reduce, *inter alia*, innovation time spans, costs and risks, and acquire greater flexibility in their operations. The improved enforceability of contracts and declining transaction and monitoring costs resulting from developments associated with globalisation have made it easier for firms of all sizes to monitor, identify and establish collaborative ventures than previously had been the case (Narula 1999). In other words, they have increased the flexibility of firms' innovatory activities. At the same time, however, they have also led to an increased level of inter-firm and cross-border competition, and led to new risks and threats for the technology-intensive firm.

These developments have profoundly affected the SME. On the one hand, SMEs have always sought to specialise in niches, given their limited resources. As such, their role as specialised suppliers to large firms has increased. On the other hand, the cross-fertilisation of technologies has meant that they also need to span several competences. This state of affairs has altered the raison d'être of the SME. It could be argued that demands for multiple technologies and growing opportunities for collaboration allow SMEs to compete more effectively with larger firms. However, these developments have created both opportunities and threats for the SME. In this paper I will argue that inasmuch as the improvements in communication and the ease of enforceability of contracts has helped the SME, it has provided at least as much benefit to the large firm too. Traditionally, large firms have had material (i.e., resource) advantages, while SMEs have had the advantages of flexibility and rapid response to change. ICTs and transaction cost reductions due to economic integration have increased the flexibility of the large firm, but the disadvantages due to SMEs' absolute size limitations may have been enhanced due to increased cross-border competition, and their need for multiple technological competences. Nowhere is this more obvious than in collaborative activity with regards innovation. It puts pressure on SMEs to be even more efficient in their use of collaboration. Although alliances may overcome barriers to growth due to size (Ahern 1993), there are cognitive limits to efficiency gains from non-internal R&D, and the extent to which SMEs can afford to do so without weakening their technological advantages.

However, it is a serious error to assume that all ICT sub-sectors and technologies can be grouped together. Some are increasingly paradigmatic and mature, while others are pre-paradigmatic and nascent. Furthermore, SMEs have different objectives and operate in differing environments, particularly with regards their relationship to larger firms. The interdependence of large firms and small firms during the evolution of new technologies and industries is best described as one of 'dynamic complementarities' (Rothwell and Dodgson 1994). Differing motivations and objectives of different types of SMEs influences the nature of their interaction with larger firms, as well as their markets.

There are clearly complex dynamics at play, but I shall concentrate on evaluating the state of affairs vis-à-vis SMEs by discussing two important concurrent dynamics. Section 2 evaluates the first dynamic examining the various types of SMEs and how the industrial structure and external environment influences their collaborative activity. Section 3 examines the second dynamic, which is sector specific and relates to the evolution of technologies, technological paradigms and trajectories. I explain how different types of SMEs tend to predominate the industry structure at a given stage of the evolution of a given core technology. Section 4 examines evidence from a survey on the collaborative activities of one particular form of the SME - the 'stand-alone' SME - in the ICT sector. My analysis is based on in-depth interviews and questionnaire surveys of over a 100 European technology firms. I discuss how these SMEs utilise R&D collaboration relative to large firms. I shall attempt to discuss the reasons for the preference of one type of collaboration over another, and the limitations of collaboration as an alternative to in-house R&D. The last section presents some conclusions.

2. The first dynamic: External environment and the differences in SMEs

The SME is not a monolithic organisational form. Apart from the obvious differences associated with different size categories[1], it is important to emphasise that there are different types of SMEs with different motivations and operational objectives. The nature of an SME's value adding activities varies considerably, and I propose that we can usefully argue that the variation in the kinds of SMEs is determined by their raison d'être, which in turn influences the extent and nature of innovatory activities, and therefore the kinds of collaborative activities they are prone to undertake. I shall argue here that there are two broad groups of SMEs engaged in the ICT sector.

The first is an industrial organisation dynamic associated with its external (and largely exogenous) environment. Although this is a large and imprecise category, I focus particularly on the competitive structure of a given industrial sector in terms of the concentration of competitors and customers in a given market, and the relationship of the SME to the large firms in the sector. The SME-large firm relationship has also been fundamentally affected by the growing trend towards products requiring multiple (and formerly unrelated) technological competences, and the growing knowledge-content in manufacturing processes and products. This is a broader non-sector specific development that has occurred in most industries to varying extents, and often linked to the process of globalisation. This development has been associated with the breadth of knowledge content in manufacturing. In addition to the declining costs of monitoring and exploiting networks, there has also been a growing need for firms to possess multiple technological competences (Granstrand, Patel and Pavitt 1997). This trend has largely been a result of the increased knowledge content of products in general, and the cross-fertilisation of previously distinct technological areas. Firms of all sizes have sought to more efficiently utilise 'non-internal' means to undertake innovation. This trend has been noted by Tidd and Trehwalla (1997), Hagedoorn (1996), Narula and Hagedoorn (1999) among others. This has affected both the large firm and the SME, since both need a broader

[1] While some countries (e.g., Norway, Denmark, Ireland) regard all firms with more than 100 employees as large, In this paper we define the SME as firms with less than 500 employees, as per the definition used by the UN, US, UK, Germany, etc.

range of competences than was previously the case. There has therefore been a consequent increased need for SMEs by large firms, who have sought to use external networks for innovation much more so than they have in the past (Narula 2001).

2.1 A taxonomy of SMEs

Despite the dominant role of the SME in many countries (in terms of number of firms) and in ICTs in particular, they have a symbiotic relationship with the large firm. That is to say, their existences are inexorably linked. Indeed, this relationship has been described as being one of dynamic complementarities (Rothwell and Dodgson 1994). Generally speaking, their competitive advantages relative to the other are different: The literature on the innovative activities of SMEs highlights the fact that they have a behavioural advantage over large firms, which have material advantages (Rothwell and Dodgson 1994). There is considerable evidence to suggest that SMEs tend to have a higher R&D productivity, and this is largely due to their ability to innovate by exploiting knowledge created outside the firm (Audretsch and Vivarelli 1996). Of course, there is great variation by industry. SMEs have tended to have an innovation advantage in highly innovative industries where the use of skilled labour is relatively important (Acs and Audretsch 1991). Their cognitive limits on resources means that most often SMEs in manufacturing are specialised in niches, but I believe a distinction can be made between two broad types of SMEs. The first are **'specialist-supplier SMEs'**, whose value adding activity is closely tied to those of larger firms, through formal and informal collaboration. Their existence is primarily in an oligopsonistic environment (i.e., few buyers, not an atomistic market). They are in the business of value adding in intermediate stages of the production chain of a large firm. Here it is important to make a further distinction between sub-groups of specialist supplier firms.

The first sub-group is the *Keiretsu SME*. These SMEs are dedicated to a single (or a few) customer, with whom there is an exclusive customer-supplier relationship. They are often single-product or single-process specialised. The proliferation of such customer-supplier relationships (often as a result of dis-integration of hitherto vertically-integrated large firms) has increased the scope for such SMEs. The SME often undertakes to fully or partly subsidise the R&D for the customer as part of the agreement, and the large firm in turn may provide or subsidise capital and/or technology, as well as long-term contracts. A subcategory of a keiretsu SME that is particularly relevant to the ICT sector are those involved in global production networks (GPN) (see Ernst 2000). Although these are also specialised in the production of sub-assemblies or intermediate products coordinated by a large firm, there is an important difference. First, there is a co-dependent relationship between all the firms in the GPN, since each partner in the network provides and receives inputs (both technologically and through products). Second they tend to be associated with locations with significant clusters of activity in their industry.

The second sub-group is the *Knowledge-based SME* - The knowledge-based SME also acts as a supplier to larger firms, but is primarily engaged in R&D and not production. It bases its existence on supplying specialised knowledge-based assets for sale to small and large firms alike. This group is not new, but its use has now proliferated as a result of the number of radically new technologies which have as-yet undefined dominant technological paradigms, and because larger firms cannot afford to undertake in-house developments of all possible technologies and possible technological trajectories. The knowledge-based MNE has proliferated in the last two decades in particular, as larger firms have systematically sought to use non-internal innovation sources. Indeed, many large MNEs require that 20% or more of their R&D budget be spent on external sourcing of R&D (Narula 2001). This is associated with the growing need for multiple technological competences, since large firms cannot hope to maintain in-house expertise at the technological frontier in all technological areas, even if the costs of doing so were not prohibitive. I will expand on this in section 3.

The second broad type of SME is the **'stand-alone' SME**. These are SMEs that produce final goods directly for atomistic markets (or industrial markets), and undertake most of the value adding aspects internally, or coordinate other SMEs who act as specialist suppliers to them. In other words, they operate much as larger firms in the same industry might, and are often in competition with them. Stand alone SMEs tend, however, to be in industries where economies of scale are not a dominant issue. The limits due to resources place them at a disadvantage, such that they must place limits (as do all SMEs) on what aspects of the value chain they can undertake in-house. This may mean, for instance, that they seek to outsource aspects of their production to other SMEs, or seek alliances with other firms in sales and marketing. Nonetheless, the focus of their activities is still based on specialisation. Their focus may be on one (or a few) products or processes, in which they are familiar with and in which have a technological advantage. That is, disadvantages due to lack of economies of scale must be offset by technological assets, or concentrate where smaller size is an attribute, such as in batch or custom production. Its existence is predicated on the presence of an efficiency (often technological) not available to the larger firm, or the presence of some other niche advantage (including exclusive access to markets). Vertical integration, and the cost savings therefrom provide larger vertically integrated firms with an advantage over SMEs, who must rely on their greater flexibility to compete effectively against the larger firms. But their most important advantage derives from utilising their more extensive external networks (and *more intensively* than large firms) of partners to achieve flexibility and cost-savings and market share.

Stand-alone SMEs may sell under their own brands (own brand manufacturing, OBM), rather than as OEM suppliers, as is typically the case for specialist-supplier SMEs. Such firms are more likely to be in direct competition with larger firms, and exploit the most important competitive advantage of SMEs, that of flexibility and rapid response to change. Although they are often in competition with the large firm, their 'point of reference' in terms of (*inter alia)* products, pricing and technology is the large firm, and thus there remains a dependence. The growing need for multiple technological competences puts pressure on the 'stand alone' SME since they also require a broader range of technologies. However, because of their constraints of size, they must therefore utilise their limited resources even more astutely maintain their technological portfolios.

3. The second dynamic: Technological evolution and SME R&D collaboration

My argument thus far has illustrated that the two broad types of SMEs have drastically different objectives, given their differing external environment and are suited to particular – and quite different -tasks. I have also outlined how (*ceteris paribus*) the nature of their R&D collaborative activities might differ. However, industries evolve over time, and this is the second dynamic that I have mentioned earlier. Following Tether and Storey (1998), who have built on the work of Abernathy and Utterback (1978), Teece (1986) and Klepper (1996) among others, there seems to be a strong correlation between industry structure and industrial evolution. However, as Tether and Storey (1998) discuss at length, while there are some regularities across industries and product classes, there are limits to generalising either using an industrial evolution argument or product life cycle argument. There are considerable variations in the industrial organisation of firms in general, and SMEs in particular due to the level of maturity of their core technologies. It is essential to emphasise that this evolutionary process which determines the kinds of R&D collaboration is also associated with *technologies*, and although there is certainly a co-evolutionary relationship with the product life cycle or industrial evolution, these arguments need to be tempered by an understanding of the underlying core technologies.

The ICT sector provides ample evidence for proposing my modification. This is a sector which is highly aggregated, covering both hardware and software elements, although most are defined as high technology industries, using the rationale of R&D intensity greater than 5%. Take a company engaged in the manufacture of instrument landing systems (ILS), which is a product that utilises a wide variety of technologies. Despite its being classified as a high-technology product, it is an industry which is mature, in that all the core technologies (software, RF transmission, sensors) are mature. The industry structure is mature and relatively stable, in that there are a few (less than 10) manufacturers worldwide, and new product ranges are introduced approximately every 5 years. The technologies can be said to be mature and post-paradigmatic, as dominant designs and well-established standards exist. There has been a consolidation of major players on an industry level, as firms that manufacture other aspects of aeronautic ground equipment have sought to 'widen' their product offerings. Thus, the same firms design and manufacture radar equipment, non directional beacons, rangefinders, and air traffic control equipment. SMEs in ILS production are stand-alone SMEs (scale economies are unimportant, because the market is limited to large airports, and each airport needs roughly two per major runway). They tend to use collaboration mainly in manufacturing (through outsourcing) but not in R&D. However, the production of ILS is about to change fundamentally because of a new core technology that is currently being introduced: ILS systems will gradually be replaced by satellite landing systems (SLS), which incorporates technology similar to global positioning systems (GPS). SLS systems are at a pre-paradigmatic stage, with the main players currently working on developing standards. In other words, while the industry is mature, the product undertakes the same functions, its core technologies are about to change. SMEs in landing systems now have to seek new sources of knowledge, and collaborate with larger firms and knowledge-based SMEs, because the SLS technology is not widely diffused, and highly specialised. This is not a unique event: A similar re-organisation occurred in the computer industry in the 1970s (at the time, dominant designs existed, and the industry was dominated primarily by large firms) with the introduction of microprocessors paving the way for a wide variety of new SMEs (Rothwell and Dodgson 1994).

I propose that technological evolution based on a core technology approach is a more accurate way of viewing industry dynamics and collaboration, because the proliferation and involvement of SMEs changes fundamentally depending on the technologies in question.

FIGURE 1 ABOUT HERE

Figure 1 gives a stylised presentation of the technological evolution of sectors, utilising two basic measures, technological uncertainty and speed of technological change (Narula 2001). Technological paradigms evolve over time from nascent, pre-paradigmatic and highly uncertain to mature, certain and slow-evolving. Note that because most products and processes are multi-technology based, we refer here to individual technologies. It should further be noted that, despite the multi-technology nature of products and processes, certain technologies are more central or 'core', while others are more marginal (Granstand et al 1997). It is possible, therefore, to argue that industries demonstrate a similar evolution. It is self evident that the framework in figure 1 is a stylised one, and that sectoral evolution is a continuous rather than discrete process. I will now discuss how the structure of industry – in terms of size of firms, and in particular, predominant type of SME – varies with the evolution in the technological characteristics of the ICT sector. Figure 2 illustrates – in the same context as figure 1 – the types of SMEs that tend to predominate during each stage of industry evolution.

FIGURE 2 ABOUT HERE

Quadrant A

New technologies begin from a basic idea, often, a fundamental invention or technological breakthrough based on an idea, which may have hitherto been a scientific theory. However, at an early stage, the technology is impractical. Its potential use is not obvious, it is not close enough to being commercial, and/or may still remain at an early stage of development. Current research interests in superconductors illustrate this well. Only the largest firms with large resources invested in basic research (such as Bell Labs, or IBM) are likely to be willing to invest in a project such as this, given that neither the time-horizon is practical, nor what variation in the technology is likely to win. There exist so many research trajectories and combinations of materials, from ceramics to semiconductors that it does not serve most firms to invest in such research. Apart from large MNEs, university departments and publicly funded facilities are likely to engage in such long-term investment. Cooperation is primarily amongst large laboratories, and primarily on a scientific level. An example of such a technology is superconductivity, which potentially has many benefits, but the technology still requires very low temperatures.

As the rate of technological innovations and breakthroughs become more rapid, and a commercially viable product becomes closer to reality, large firms and universities may create (or may *have* to create) knowledge-based SMEs as spin-offs, as important scientists involved seek more control of their inventions and the possible returns. Scientific personnel at the cutting edge of new technologies are rare, and this may be the only way to keep them. In addition, large laboratories and firms do not act as the best incubators for new, nascent technologies, which need more flexibility and a more organic organisation, a primary advantage of an SME. Besides, by doing so, it insulates the large firm from taking additional risk and minimising investment, by allowing external agencies in sharing the costs. This is currently the case with much genetic research, but ICT firms in the 1980s and 1990s undertook similar alliances in internet technologies. The SME can seek additional resources from venture capitalists and public funds. At the same time, the large firm often have an option to acquire the discoveries of the Knowledge SMEs if it makes a move towards more commercialisable technologies. Nonetheless, the basic nature of the research means that few such Knowledge-based SMEs will exist, outside dedicated university-based research centres.

<u>Quadrant B</u>

Eventually, however, as innovations move towards the point of resulting in patents which may be commercially exploited, an increase in such Knowledge SMEs may be expected. Prototypes of products now exist, and the SME needs not only technological resources, but also manufacturing and managerial personnel and expertise. At this stage, the more successful knowledge-based SMEs become stand-alone SMEs, but in the early stages of quadrant B these will be an exception rather than the rule. Increased financial flows from both large firms and venture capitalists will fuel the movement of the best scientists, as there is a race to establish a dominant technology, and thus to define the paradigm. This is the situation that the biotechnology and robotics industries find themselves today. The software industry was also at this stage in the late 1970s and early 1980s. Eventually, as the Knowledge SMEs begin to grow, spin-offs will begin from these companies, creating additional Knowledge SMEs. Large firms will begin to acquire the more successful companies in these sectors, attempting to internalise and apply these new technologies to their existing products and processes. Acquiring these Knowledge SMEs allows the larger firm to integrate the new technology to their existing R&D activities, and, it is hoped the large resources available to the big company will help to reduce the 'distance to market'.

Toward the end of quadrant B, products based on the new technologies begin to enter the market, although they will tend to be of a specialised nature, due to their high cost of production. There is a high concentration, as only a few firms will have the technological competences necessary. Technological change remains rapid, and leadership moves from one company to another, with no clear dominant player. Production is predominantly undertaken by stand-alone SMEs, which operate on a small scale, since competitive advantage is based on technological assets, rather than price.

Quadrant C

By quadrant C, the technology will have been diffused, and the technical difficulties of large scale production will have been overcome. Production in small batches will gradually be replaced by large-scale production. These are either by former stand-alone SMEs, which have rapidly expanded their operations, or by large firms that have acquired the technology from SMEs, through alliances or M&A. As the technologies become diffused and increasingly codifiable, firms will seek to outsource or engage in alliances[2] for components and sub-assemblies from stand-alone SMEs and specialist-supplier firms which possess the appropriate niche technologies. These may develop over time into global production networks. This type of SME becomes increasingly important as the technology becomes codifiable and increasingly mature, such that large firms seek to use outsourcing. SMEs within the network undertake most, if not all, the R&D required for their niche input into the process, and this specialisation leads to a co-dependence between the various firms – SME and large – in the network. The dominance of Knowledge SMEs *that themselves have core technologies in quadrant C* gradually declines, except perhaps in niche sectors. It should be emphasised however, that as new technologies that are pre-paradigmatic (quadrant B) are introduced into existing (quadrant C) products, firms will need to seek alliances with them. For instance, currently substitutes for LCD displays are being developed which are less fragile and more flexible(quadrant B), and notebook computer manufacturers (a quadrant C product) are seeking to identify the most viable of the various alternatives. As technological change becomes less rapid towards the end of quadrant C, much of innovation moves towards development-type work, and incremental improvements of increasingly mature products.

[2] The decision to ally or outsource depends on a) whether the specifications for the sub-assembly are codifiable, and multiple, substitutable sources exist; and b) whether the technologies used in the sub-assembly are not central to the outsourcing firm. In general, non-internal sources are used as the technology moves towards quadrant D. That is, these technologies are rapidly becoming mature and post-paradigmatic. See Narula (2001) for further elaboration on the decision factors behind outsourcing and alliances.

Quadrant D

By quadrant D, the technology is mature. Technical change is now slow, with minor but consistent innovations over time, and can be regarded as post-paradigmatic. The technology is to a great extent codifiable, widely disseminated, and the property rights are well-defined. Innovation is rarely patentable in these technologies, where applications development account for most innovatory activity. Competition shifts towards price, economies of scale, and downstream activities in order to add value, as the original product is priced as a commodity. SMEs simply do not have the size advantages to engage in production (except perhaps in specialised niches), and stand-alone SMEs are the exception rather than the rule. The main opportunities for SMEs are as keiretsu-type MNEs, acting as specialised suppliers to large firms. Collaboration tends to take the form of outsourcing. Indeed, in these technologies, large firms expect suppliers to undertake much of the investment in development of new products and processes on their behalf. This is particularly common in the case of equipment suppliers to large firms in mature sectors, who expect the suppliers (whether large or small) to invest in R&D as a substitute for their own R&D expenditures (Fritsch and Lukas 2001). This is the case even where the supplier firms have core technologies in earlier quadrants.

4. Some evidence: Stand-alone SMEs in the ICT sector

In this section I address the question of R&D collaboration by ICTs firms, illustrating the differences between SMEs and larger firms. I focus on what we have earlier described as ‘stand-alone’ SMEs. My discussion is based on data that derives from the TIK-R&D database, a larger ongoing survey being conducted on the internationalisation of R&D by European based MNEs. The criteria for selection of these firms has been a) That they were majority-European owned as of 1998, b) engaged in manufacturing, c) have annual R&D expenditures greater than (approximately) US$1 million and/or 10 full-time R&D employees. Although the database consists of 110 European firms, 47 of the total are in the ICT sector. In order to avoid any possible bias due to industry differences the sample is further narrowed by excluding firms primarily engaged in software and ICT service firms. Firms in the sample are engaged in the design and manufacture of electronics-based hardware, including medical electronics, avionics, scientific and measuring equipment, and industrial electronics. I have attempted to match 'similar' firms together, in terms of technology intensity, primary technologies, but not nationality, structure of ownership or age of firms. Furthermore, SMEs that act primarily as suppliers to larger firms were excluded, because they are involved in a 'keiretsu' –like symbiotic relationship. The final sample available for the analysis is 13 SMEs and 12 large firms. The UN definition of SMEs to include firms with less than 500 employees has been used.

The firms in my sample, like most ICT firms, can be classified in quadrant C, although certain industries have progressed towards quadrant D (PC manufacturers, hard disk technologies), where products are mature and compete mainly on price, having taken on a commodity-type nature. It is true that while new technologies do exist that are still pre-paradigmatic (nano-electronics, artificial intelligence, neural networks), but broadly speaking firms in my sample are predominantly paradigmatic. Clear dominant technologies have presented themselves, and *de facto* standards established. Unambiguous technological trajectories exist, and most innovatory activity is focused around the dominant paradigms. Technological change remains rapid, but mainly through incremental, rather than radical innovation. Innovation also tends, for the most part, to be undertaken either in applied research, or in development, and rather rarely in basic research. Since innovation is built around clear trajectories, the nature of the incremental innovation is known, what is unclear is who will be first to the market. Although property rights are clearly defined in quadrant C, the rapidity of change means that firms maintain their competitive advantage by being first to innovate and exploiting the lead time of being 'first'. In our sample, the life cycle of products averaged around 12-18 months, a pace usually dictated by 'major players' (i.e. large firms).

FIGURE 3 ABOUT HERE

Thus far, these tendencies apply universally to all firms in quadrant C. However, R&D in quadrant C (and in ICTs in particular) is resource intensive, both in terms of capital and knowledge. Most products are multi-technology in nature, and multiple competences are needed. Figure 3 illustrates the kinds of technologies that a typical ICT firm may require. Few firms, regardless of size, can afford to maintain R&D facilities with world-class competences in so many different sectors. This is particularly so in the case of SMEs, which by definition have limited resources. Even if SMEs maintain twice the level of R&D intensity as a large firm in the same industry (which typically might be 5%), a company of 500 employees might maintain an R&D department of about 50 people, while a large firm with 5000 employees might have an R&D facility of 250 people.

TABLE 1 ABOUT HERE

Table 1 gives a rough idea of the differences in size between the large firms and the SMEs. Large firms in our sample spent 5 times more on R&D than the SMEs. However, in terms of R&D employees, large firms were on average only three times larger. Nonetheless, the average size in terms of R&D employees of SMEs in my sample was 42. There are only so many specialisations that an SME can maintain with such a small absolute R&D headcount. There is a certain minimum threshold size of a research group within any area, and this represents a real constraint to SMEs. In addition – and this is true for firms of all sizes - there is no guarantee that the research group in any given facility will in fact consistently innovate at the technological frontier, and within the dominant paradigm, even if world class researchers are present. In other words, there are cognitive limits on what firms can and cannot do (Pavitt 1998). Firms therefore are dependent on the *last-best* (i.e., state-of-the-art) innovation. If a firm is engaged in developing an innovation in a given technological paradigm, it must strive to improve (or at least take into account) <u>not</u> its own last-best innovation, but the last-best innovation that has been patented, or that is the dominant design on the market[3], even if this was created by another firm. Thus its path-dependency is always tempered by the state-of-the-art, and this means that roughly speaking technological trajectories of different firms within any given technological paradigm are similar.

There are therefore two pressures on ICT firms – firms are forced to maintain an equivalent breadth of R&D competences as other firms in the same industry, and at the same time maintain their innovative activities at the industry rate of evolution. The benefits of smallness – which are variously associated with greater flexibility and rapid response – compensate for some of the disadvantages of size, and may allow SMEs to maintain the rate of technological change. But they do not necessarily help SMEs when it comes to the absolute limit on its resources.

Keep in mind too, that SMEs have also to devote resources to other aspects of the value chain. They must seek to achieve economies of scale in production, and also to effectively market their products, and provide support services. In quadrant C, market share considerations are at least as important as technological assets – it is insufficient simply to have the best product, if no one will buy it. More importantly, if a competitor's technology is accepted as the industry standard, it can threaten the existence of the firm.

[3] Numerous examples of technically sub-optimal innovations defining the technological trajectory exist (e.g., Betamax vs. VHS, Macintosh vs. PC). Perhaps the best documented example is of the QWERTY keyboard (David 1985)

It is impressive, nonetheless, that the SMEs in our sample employ more people relative to their R&D expenditures than large firms, and the answer lies to some extent in their greater use of non-internal R&D sources. Larger firms tend to use a smaller percentage of their R&D budgets (on average 12.4%) to outsource and engage in strategic alliances than SMEs which utilise on average 21.9% of their R&D budget (Table 1). The limitation in resources, and the need to maintain the firm's position on the technological frontier of the various technological areas that it requires is mainly responsible for the growth in the use of non-internal R&D activities in both large and small firms. Our use of the term 'non-internal' is a deliberate one, and is intended to include both external activities (arms-length relationships such as licensing, R&D contracts, outsourcing - and other customer-supplier relationships) and quasi-external activity (such as strategic alliances, which are taken to include a myriad of organisational modes [Narula and Hagedoorn 1999]). Non-internal activities, apart from the obvious benefits of exploring new areas and instigating radical change, have the advantage of being a 'reversible' form of investment (Gambardella and Torrisi 1998). The capital needed is smaller, and the risks are substantially reduced, and in case of failure or organisational crisis, limited damage is inflicted on the primary operations of the firm. Nonetheless, the tacit nature of innovation, and the risks associated with loss of technological competitiveness, encourage a high level of in-house R&D activity.

External acquisition of technology is most easily done when the technology behind the product is codifiable and standardised and for which *multiple non-distinguishable* sources of these inputs are available (Narula 2001). The same argument holds true for R&D activity, since R&D output is partly tacit, externalisation of R&D means that the firm only gets the codified results, not the accumulated person-embodied skills. As has been noted elsewhere, even where firms outsource, they maintain a minimum level of in-house capacity in those technologies in order to decipher and utilise them (Veugelers 1997). In other words, R&D outsourcing is only undertaken where doing so is cost-effective AND does not threaten the competitive advantages of the company. Having a single source or single buyer may prove to be most cost-effective, but it is generally accepted that low costs do not always translate to the best technology.

The manner in which firms select external vs. internal R&D acquisitions is associated with the centrality of the technological competence to the firms' activities (Narula 2001). Firms will, <u>ceteris paribus</u>, prefer to undertake innovative activities in their distinctive competences through in-house R&D. Although there is considerable overlap (figure 3), broadly speaking niche and marginal competences are strategically less significant, and can be undertaken through alliances. However, the strategic importance of these technologies determines to what extent their development can be externalised. This, in turn, is determined by the extent to which the technology is tacit, the extent to which collaboration is required to utilise it, and to what extent the partner's activities need to be monitored.

Background competences are, by and large, the area where outsourcing is primarily used. In general, it would seem firms prefer to undertake research in their distinctive competencies in-house as much as possible. There is, however, considerable overlap in the use of in-house R&D and alliances for niche competences, and between outsourcing and alliances in marginal/peripheral competencies. SMEs tend to be more concerned about their loss of technological assets than large firms. SMEs tend to use non-internal means with a great deal of care, bordering, in some cases, on paranoia. One firm said,

> 'Because we do not have the resources [ourselves, and have to outsource], we make sure none of our partners has enough of our technology to become a competitor. We provide the macro-specifications to one partner, which does the design. But we have a different company to do the manufacturing of the relevant sub-assembly. We make sure that no company is responsible for more than one sub-assembly ,and always pick companies smaller than us.'

Another manager agreed;

> "We use more than one supplier, our products are based on several boards. Each supplier produces only one board, because we don't want any supplier to have access to our complete product. We might be able to get a lower price, but we don't want to be in a position that the supplier is able to become a competitor. Non-disclosure agreements aren't enough."

In general, the vulnerability due to smaller size means that SMEs have to be more wary of alliances. One of the SMEs in our sample considered alliances unacceptably risky:

> "These competencies are too important to us….we have spent many years building our strength in these sectors….frankly we have world class competences……I am loathe to consider letting anyone near our technology. We only use alliances [in these areas] if we have to."

In general, however, SMEs use non-internal means to a greater extent than large firms, because they can maintain sufficiently high level of in-house competence in only a few (or even a single) technological areas. This represented an advantage of the SME, according to one manager who argued,

> ‘We are not married to a given technology, and that is precisely why we are successful. If we did our own research, we would have a vested interest in a particular technology, even if it is not the best, and this would eventually become a problem.’

Thus, there are many more technologies which they have to acquire externally. The use of alliances in connection with niche sectors was, in general, associated with firms that had limited R&D facilities and/or considered that there was a large technological gap between their technological competencies and the market leaders. SMEs considered alliances as a way of extending their technological competences more than large firms, but only when they were unable to do so through outsourcing. For instance, one medical equipment manufacturer did not have the resources to invest in the next generation of displays. Although LCD technology has become more mature over the last 5 years, it remains capital-intensive, and proprietary technology rests with a handful of companies. It therefore sought an alliance with a US company which is a market leader in medical equipment, many times their size. The US firm did not currently compete with them in their particular product segment, and agreed to share the technology and to distribute their products in the US. As a manager pointed out,

> "It’s a risk [to ally with such a large player], but the cost of developing our own display systems would use up almost our entire R&D budget for a couple of years…and our old product range was [beginning to look] old…[They]…have the technology lying around, because they have more people in their R&D facilities than we have in our entire company…[if they wanted to] they could buy us out, whether we had a partnership with them or not [so it doesn’t matter whether or not we partner with them]."

The point I want to make here is that first, there is a limit to how much of a firm’s R&D activities can be externally acquired particularly due to technological and strategic considerations. Second, even if costs are reduced through the use of non-internal means, they remain non-trivial, and the constraints of absolute limits of resources remains.

TABLE 2 ABOUT HERE

Both large and small firms have similar motives to undertake inter-firm R&D collaboration (Table 2). The primary motivation for both groups of firms was not considered to be the reduction of risks or costs, but the reduction of innovation time span, and the access to complementary technologies. However, larger firms are in a better position to establish partnerships, because they have more to offer. SMEs have fewer technological assets with which to barter, while the technological portfolio of large firms is larger, and besides they can offer cooperative agreements at other levels too, from either production or their marketing and sales operations. This is apparent from Table 3.

TABLE 3 ABOUT HERE

Where SMEs concentrate their activities in-house, they are still forced to consider alliances with larger firms, simply as a means of getting access to marketing and sales channels. A telecommunications equipment company explained,

> ‘Although we do not need anyone for technology, we are not able to offer a ‘suite’ [an integrated package of products]. The way of the future is systems integration, and it is the key. Customers want our equipment to work in tandem [with products of other manufacturers]. Our competitors are all large and can offer an integrated package, we can’t. So we are looking for a partner who will sell our product, but we are faced with a dilemma, because the only companies who make [the other parts of the suite] are our competitors.’[4]

In general, both large and small firms show a preference to outsource applied research and product development to public research institutes and universities because of the fear of giving away their technology to a competitor or potential competitor. Although our data is by no means conclusive, anecdotal evidence suggests that SMEs tend to engage in fewer strategic alliances with other firms, preferring to outsource wherever possible. It should be noted that there is a lower limit to the extent to which any firm (but particularly SMEs) can use non-internal sources as a substitute for internal R&D. Both alliances and outsourcing require complementary resources. Some level of in-house capacity is essential to absorb the externally acquired information. Furthermore, alliances in particular (compared to outsourcing) require considerable managerial resources, not just because of the collaborative aspect, but also because alliances tend to be used where technology is tacit. Again, limited human resources means there is a limit to what percentage of a smaller absolute size of personnel can be devoted to managing alliances.

5. Concluding remarks

[4] Two months after the interview, this SME was acquired by a large competitor.

This paper has highlighted the increasing imperative of ICT firms to expand their portfolio of technological competences, and that this applies to SMEs as much as it does to large firms. Fortunately, reduced costs of enforcing agreements, the decline in barriers to trade and investment and the improvements in communications have improved the efficacy of cooperative ventures, especially for R&D.

I have focused on ‘stand alone’ SMEs in the ICT sector, which are engaged in direct competition with larger firms, and broadly speaking are ‘mini-large firms’. Both large firms and SMEs need roughly the same breadth of technological competences, as multi-technology products are the norm in the ICT sector. For both groups of firms, maintaining such a large portfolio of technological competences is difficult, but more so for the SME. The use of non-internal technology development through outsourcing and alliances has provided benefits for both types of firms, but particularly so for the SME.

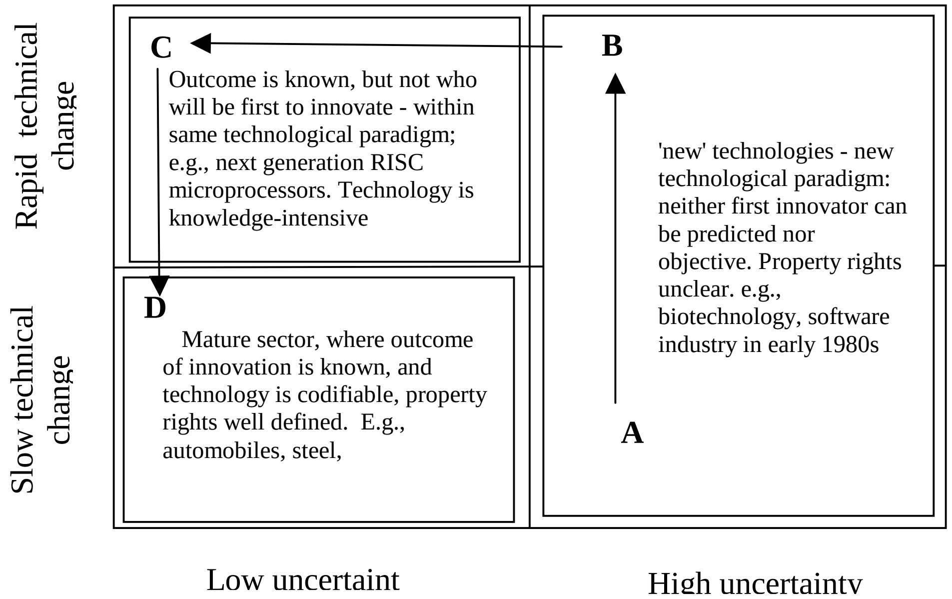
SMEs tend to maintain a smaller group of in-house technological competences, and are generally able to leverage their limited R&D resources more efficiently. They tend to use almost twice as much of their R&D expenditures towards R&D collaboration than large firms. However, there are cognitive limits to what SMEs can do, and how much they can use non-internal R&D, due to their absolute size limitations. Nonetheless, the more successful SMEs have been able to maintain their competitive position through a more astute use of non-internal R&D, with less in-house R&D than larger firms.

However, collaboration has its price. First, because even where non-internal means are used, some level of in-house competence must be maintained in order to understand and integrate the various technologies together. Second, most R&D alliances have a very low success rate. A failure rate of 50% was judged by firms in my sample to be very good indeed’. For a large firm, these losses are easier to accept as they often have multiple, redundant, back-up agreements with several firms. In addition, large firms have more to offer in a partnership, and can easily find alternative sources, compared with SMEs. SMEs are more careful about picking partners because they have limited opportunities to fail. There are also strategic reasons to be careful: partnering with a larger firm can lead to a loss of technological competence.

It seems that there is a limit to how much of a firm’s R&D activities can be externally acquired particularly due to technological and strategic considerations. In addition, even if costs are reduced through the use of non-internal means, they remain non-trivial, and the constraints of absolute limits of resources remain.

We have not discussed the international dimension of collaborative activity. Firms in the ICT sector all have a growing need to monitor the innovation systems of other countries than their own, and to be located close to both their markets and their competitors to maintain their competitiveness. They need to do so both through R&D facilities abroad, and through alliances. However, SMEs are again constrained by their resources. Even alliances require some level of physical presence, and the threshold level to establish such facilities is often prohibitively high for SMEs.

Stand-alone SMEs in the ICT sector are an endangered species. In the long run, these firms are faced with 3 options: expand, be acquired, or specialise. This is in fact what might be predicted from my discussion of industry evolution. As technologies become more mature and diffused, competition shifts away from technological excellence *per se*, and towards price. Size and costs become more critical. As such, if SMEs specialise, they can maintain their position on a technological basis where small size and flexibility allow SMEs to be at least as innovative as large firms, if not more.

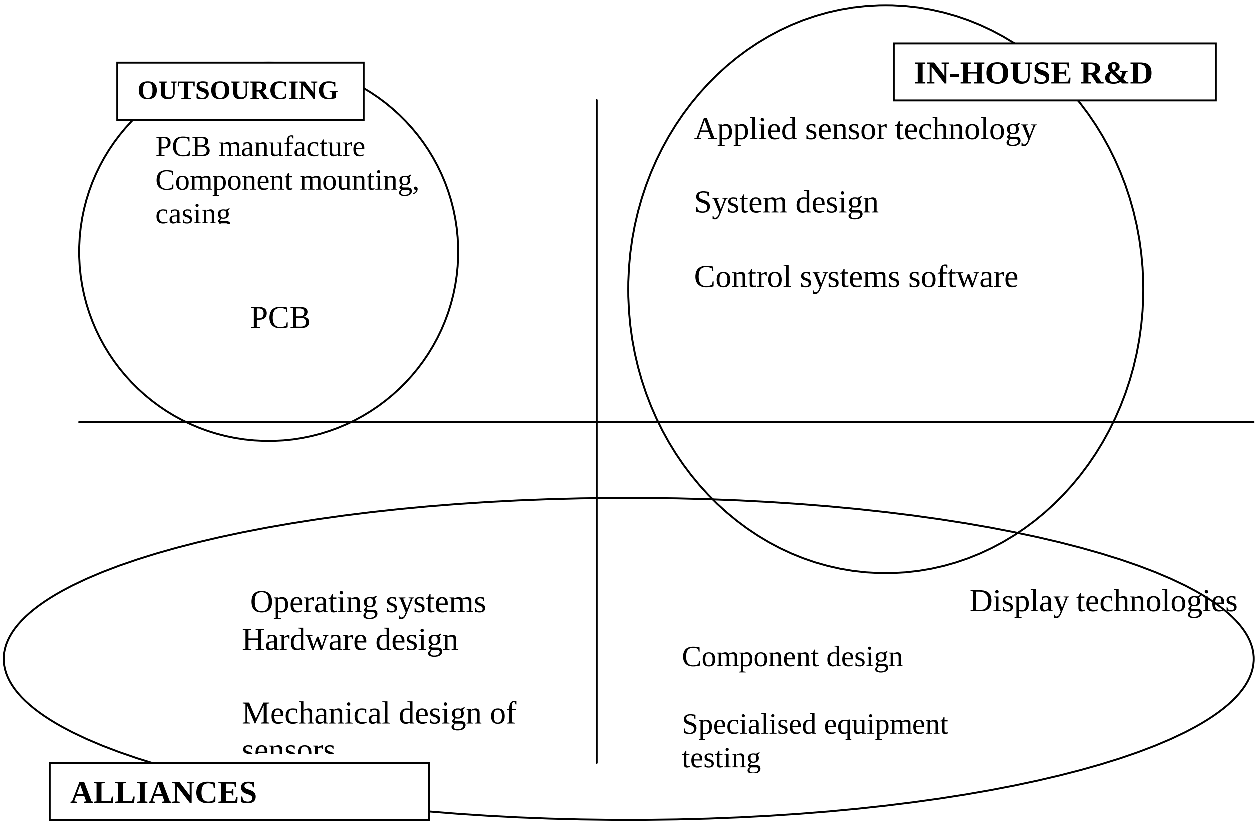


Source: Narula (2001)

Figure 1: Technological evolution with a given paradigm

Quadrant C **GPN SMEs** **Knowledge SMEs** Stand-alone SMEs	**Quadrant B** **Stand-alone SMEs** **Knowledge SMEs** GPN SMEs
Quadrant D **Keiretsu SMEs**	**Quadrant A** **Knowledge SMEs**

Figure 2: Types of SMEs at different stages of an industry's evolution



Source: Narula (2001)
Note: No attempt has been made to locate technologies on a relative basis within any given quadrant.

Figure 3: Distribution of competences of an ICT firm, based on managers' perceptions

		SMEs	Large firms
Mean R&D expenditure	(million US$)	4.15	21.54
Mean R&D employment		42	129
% of R&D in home location		90.7	57
% of firms with overseas R&D labs		36.4	77.8
Percentage of firms with R&D facilities in the US		27.3	66.7
average size of R&D facilities in the US (employees)		8.2	96.5
% of R&D acquired externally		21.9	12.4
% of firms with < 20% external acquisition		28.6	100

Source: TIK-R&D database

Table 1: Some basic indicators

	SME mean	SME % major or crucial importance	Large firms mean	Large firms % major or crucial importance
reduction of costs	2.4	40	3.0	28.6
reduction of risks	2.5	30	2.9	14.3
reduction of innovation time	3.4	70	3.3	42.9
access to markets	2.4	30	2.2	33.3
access to complementary technology	3.6	60	4.6	100
setting standards	2.7	30	2.7	42.9

Source: TIK-R&D database

Table 2 The importance of different R&D motivations for ICT firms

What kind of research do you undertake with your partners?

	SMEs	Large Firms
	% of firms that responded often' or 'most of the time'	
basic research	0	0
applied research	50	14.3
development	50	71
design	10	43
production and marketing	20	71

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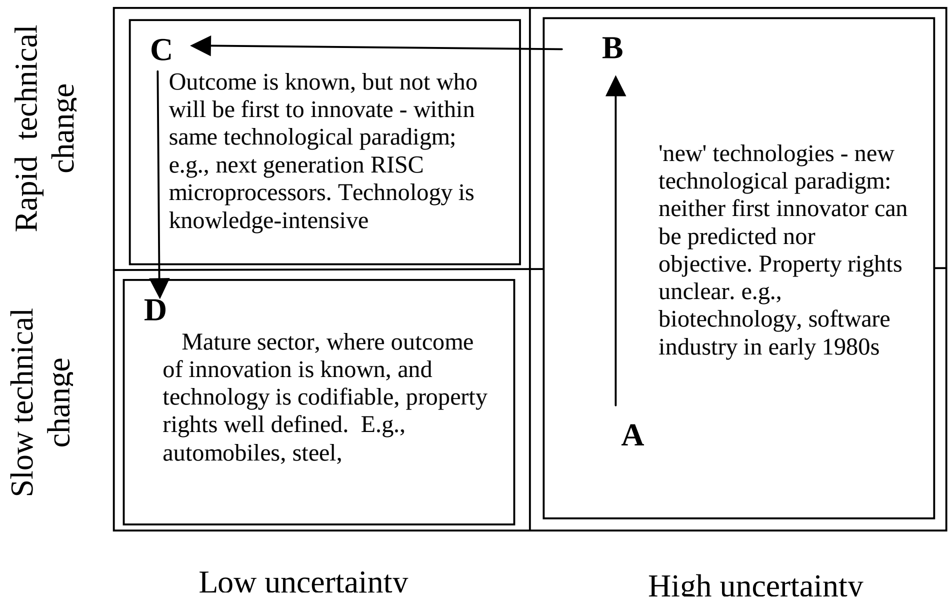

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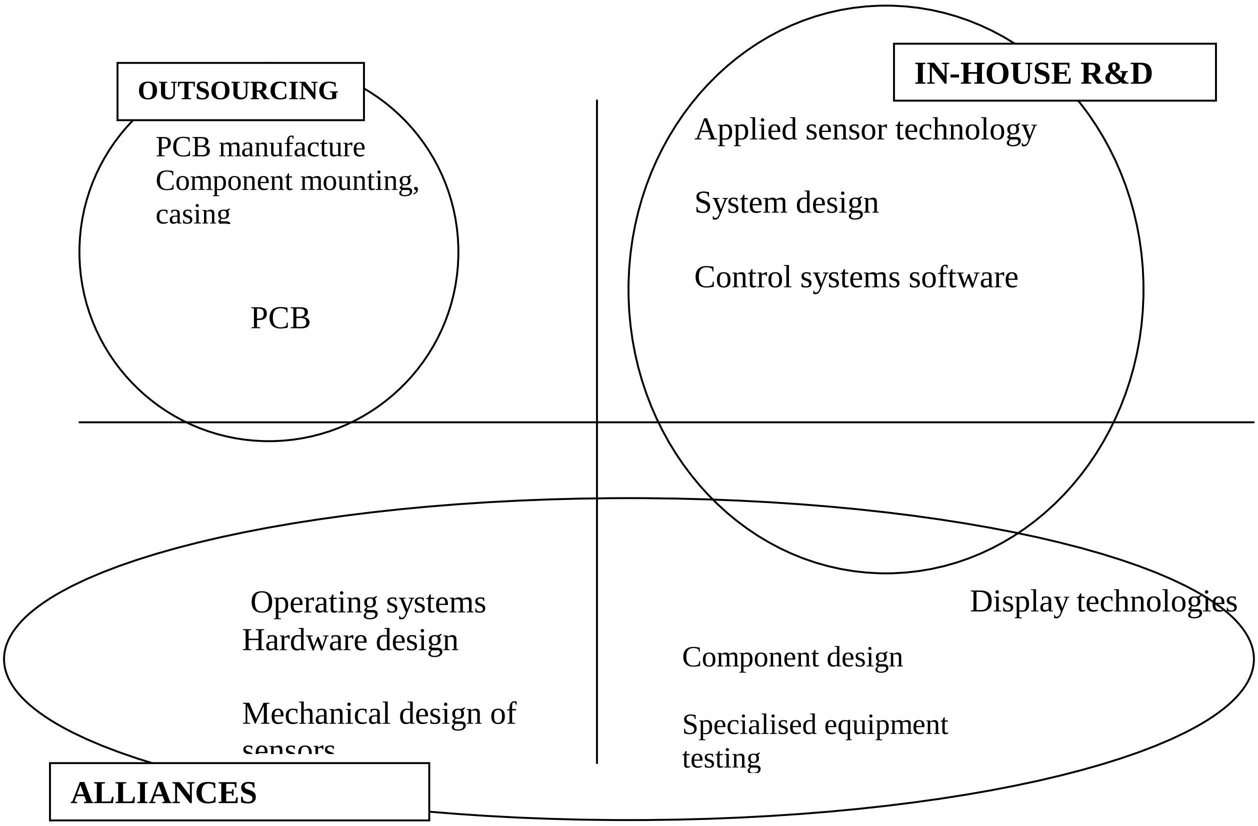

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