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THE ECONOMICS OF STRATEGIC R&D ALLIANCES – A REVIEW WITH FOCUS ON THE ICT SECTOR***

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ABSTRACT: Inter-firm collaboration in R&D is not a new phenomenon. What is new, however, is the rapid increase in such collaboration since the 1980s in parallel with increasing competition. Terms like “strategic R&D alliances” or “alliance capitalism” have been coined to conceptualise these patterns of collaboration and competition in industry. The aim of this paper is to briefly review theoretical frameworks to understand the formation, functioning and effects of strategic R&D alliances in industrial economies, to define more precisely and typologise different types of alliances, and to provide a descriptive analysis of alliance activity in the ICT sector as an empirical illustration. The empirical part of the paper draws on the world’s largest database of strategic R&D alliances and related research to identify characteristics of alliance activity in core ICT technology fields of special interest from a Finnish viewpoint. The paper concludes by discussing frictions between theoretical interpretations and empirical examples of alliance activity, the main results of the descriptive analysis, and suggests some new research directions to further our understanding of technical change and innovation in the ICT sector.

Keywords: inter-firm collaboration, coordination, strategic R&D alliance, ICT-sector

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TIIVISTELMÄ: Yritysten välinen tutkimus- ja kehitysyhteistyö on ollut jo kauan merkittävä tekijä teollisessa kehityksessä. Lisääntynyt kilpailu on kuitenkin erityisesti 1980-luvulta lähtien kasvattanut nopeasti tätä yhteistyötä ja muuttanut sen luonnetta. Käsitteet ”strateginen T&K-allianssi” tai ”allianssikapitalismi” ilmentävät näitä samanaikaisen yhteistyön ja kilpailun malleja. Tutkimuksen tavoitteena on ollut kuvata teoreettista viitekehystä, jolla voidaan ymmärtää strategisten T&K-allianssien syntyä, toimintaa ja vaikutuksia, tyypittää tarkemmin eri liiansseja sekä käyttäen empiiristä aineistoa analysoida deskriptiivisesti allianssiaktiviteetteja. Aineistona on käytetty suurinta kansainvälistä strategisten T&K-allianssien tietokantaa sekä muuta alan uusinta tutkimusmateriaalia painopisteenä suomalaisen ICT-alan ydinalueisiin liittyvät allianssit. Tutkimuksen johtopäätöksissä vertaillaan teoreettisia tulkintoja ja empiirisiä havaintoja, kerrotaan deskriptiivisen analyysin päätulokset sekä ehdotetaan joitakin suuntaviivoja jatkotyölle ICT-alan teknologisen muutoksen ja innovaatioiden vuorovaikutuksen ymmärtämiseksi.

Avainsanat: yritysyhteistyö, koordinointi, strateginen T&K allianssi, ICT-ala

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1 INTRODUCTION

1.1 Background

Collaboration in research and development (R&D) is not a new phenomenon. What is new, however, is the rapid increase in such collaboration since the 1980s in parallel with accelerating technological change, the internationalisation of firms and globalisation of the world economy (Caloghirou et al. 2003). Further, the development of information and communication technology (ICT) infrastructures has accentuated the importance of managing knowledge flows rather than the flow of goods. As a consequence, R&D is increasingly undertaken in networks spanning different technology fields, industry and national boundaries. New forms of collaboration are also emerging, ranging from informal bilateral collaboration to highly complex multilateral and multi-layered networks. At the same time competition is intensifying due to the global reach of firms.

Taken together, these developments have prompted a major reorientation in the R&D and innovation strategies of firms (de la Mothe & Link 2002). Firms have to become engaged in global knowledge exchange in their upstream activities, while they often also have to compete with their collaborative partners in the downstream markets. Concepts such as “strategic alliances” or “alliance capitalism” have been coined to interpret the extent and nature of these patterns of collaboration and competition (Comes-Casseres 1996; Dunning & Boyd 2003). A strategic alliance might – for starters – be defined as a contractual relationship characterised by the commitment of two or more partners to reach a common goal. A strategic alliance coordinates the activities of two or more independent partners by contract, even though it falls short of the full integration of these partners.

As already hinted above, this paper focuses on one specific type of strategic alliances, namely strategic R&D alliances between industrial firms. Moreover, the paper discusses inter-firm strategic R&D alliances in the context of the ICT sector. This limitation to the ICT sector is motivated by the strong international position that Finland has had in this sector since the mid 1990s. The ICT sector is also especially interesting from the viewpoint of strategic R&D alliances due to the systemic nature of innovation. Various ICT technology fields are typically complementary due to interoperability of ICT infrastructures, equipment and services through standardization. In addition, the digitalisation of networks and the emergence of the Internet are blurring technology and industrial boundaries, deconstructing value chains and reshaping business models. (Paija et al. 2001; Li & Whalley 2002). In this context, strategic R&D alliances might be considered as an especially important means of firms to cope with these changes; to access complementary technologies, to manage standardization and uncertain technological change, and thereby facilitate both collaboration and competition at the same time.

1.2 Aim and structure

This paper should be read as an introduction to further research on strategic R&D alliances within the Industrial Economics and International Business programme of ETLA that will focus on the position of the Finnish industries in the global division of labour in R&D.

The aim of this paper is to review theoretical frameworks of relevance to understanding the formation, functioning and effects of strategic R&D alliance in industrial economies, to introduce the so-called CATI database on strategic R&D alliances in the Finnish context, and to illustrate and discuss the nature of strategic R&D alliances in the ICT sector as a special case. The ICT sector is presently of primary interest to the Industrial Economics and International Business programme, and this paper also contributes to the 'Innovation, regulation, and the changing terms of competition in wireless telecommunications' – joint project with ETLA and the Berkeley Roundtable on the International Economy (BRIE) at the University of California at Berkeley.

The paper is structured as follows. The second section briefly introduces different theoretical frameworks applicable to understanding strategic R&D alliances. The third section discusses the definitions of strategic R&D alliances and distinguishes between different types of alliances. The fourth section introduces the CATI database through combining the descriptive analysis of strategic R&D alliances in the ICT sector with reviews of previous empirical contributions with a focus on the ICT sector of specific interest from a Finnish viewpoint. The fifth section summarises the paper and identifies some future research directions.

2 A REVIEW OF THEORETICAL FRAMEWORKS

2.1 An eclectic framework

Theoretical interpretations of why firms form strategic R&D alliances, of the functioning, and effects of such alliances, essentially concern issues related to the coordination of activities in the economy. In standard textbook economics coordination is achieved through the price mechanism, whereby questions related to why and how firms extend their boundaries to interact with each other are largely ignored. Nonetheless, beyond textbook economics there is a vast literature on such issues. This literature ranges from contributions within mainstream economics, and various refinements thereof, to the fields of strategic management and organizational sciences.

It is outside the scope of this paper to review all of these theoretical frameworks. Accordingly the ensuing review will be a highly selective and brief one, focusing on those frameworks that appear to have been the most commonly referred to in the literature that we have reviewed while preparing this paper. The frameworks reviewed in this paper are illustrated in figure 1 below. Together they constitute an eclectic framework, since they contribute in complementary ways to the understanding of strategic R&D alliances. More comprehensive reviews are found in Lemola (1994), Hagedoorn et al. (2000), and Caloghirou et al. (2003).

The three first theoretical frameworks in the upper part of the figure cover various contributions seeking to interpret why firms extend their boundaries in the first place, and coordinate their R&D activities through strategic alliances. The point of departure is in transaction cost economics as a framework for interpreting the determinants of ‘make or buy R&D’ decisions, with a specific focus on the costs arising from transacting with other firms. This framework finds applications in interpreting vertical strategic R&D alliances with upstream suppliers. However, an extension is needed to cover horizontal alliances, as well as the complexities and dynamics of technological change and innovation.

The notion of complementary assets is one such extension. This second framework appears to be especially relevant for interpreting strategic R&D alliances in the context of the ICT sector as it is characterised by rapid and discontinuous change, complex and complementary technologies, systemic innovation and related standardisation. Finally, one might distinguish the resource-based view of the firm as a partial critique of transaction cost economics. This third framework is useful for interpreting the conditions conductive for the exchange, absorption and appropriation of knowledge, and hence also touches on issues related to the stability and success of strategic R&D alliances.

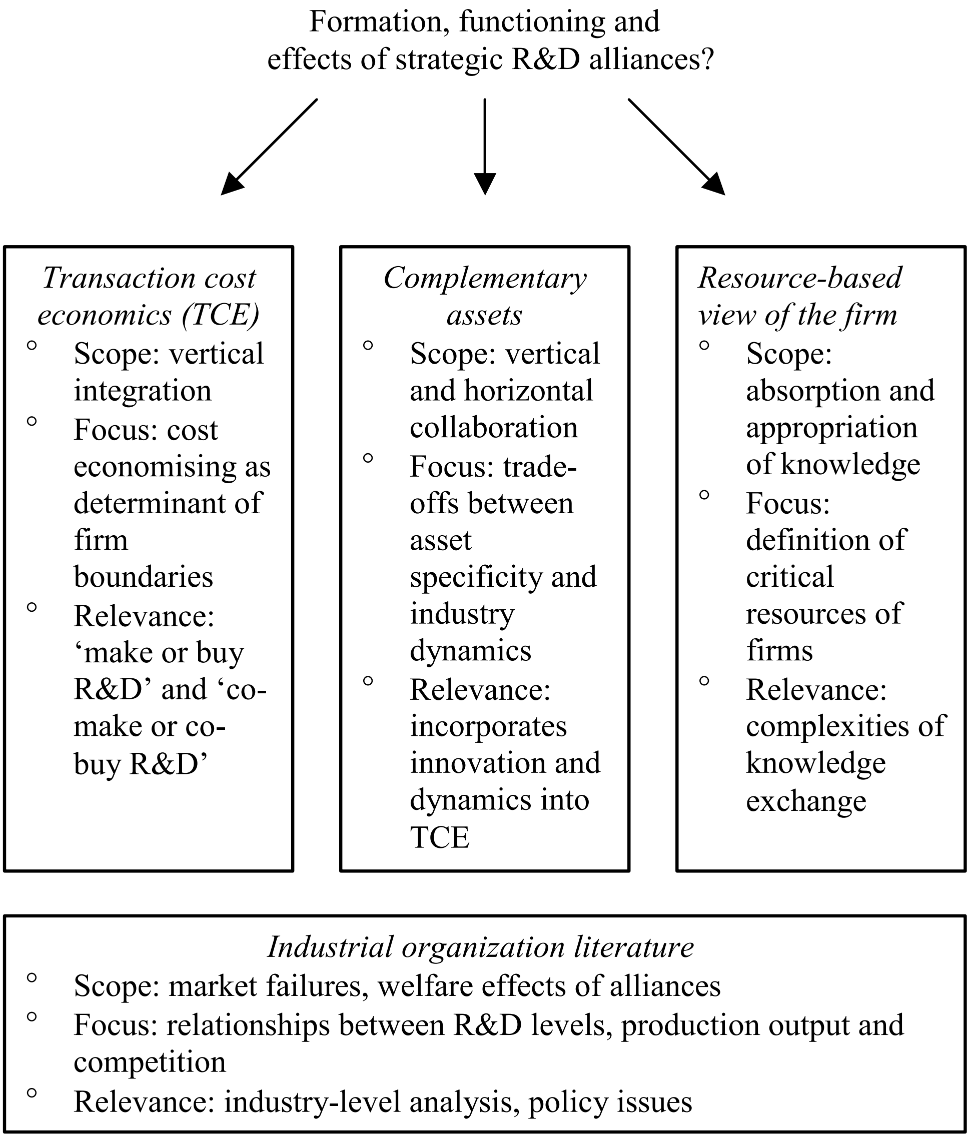

Figure 1. Theoretical frameworks applicable to the analysis of strategic R&D alliances

The fourth theoretical framework in the lower part of the figure covers various contributions in the tradition of industrial organisation as a sub field of mainstream economics. These contributions depart from the firm level and issues of coordination per se. Instead they focus on the broader welfare effects of strategic R&D alliances for society at large in terms of the relationships between joint R&D levels, production output and the nature of competition. They cover a range of approaches with a common denominator in a game theoretic framework, in which the welfare effects of alliances are analysed under various assumptions regarding collaborative R&D and competition in the downstream markets.

2.2 Transaction cost economics and the boundaries of the firm

Interpretations of why alliances are formed essentially concern the reasons for why firms extend their boundaries through collaborative agreements, of which a strategic R&D alliance can be considered as a specific one. The discussion of the boundaries of the firm can be traced back to the seminal article by Ronald Coase from 1937. Coase (1937) was concerned with why firms exist and grow in the first place, given the theoretical emphasis on the market as an efficient coordinator of economic activities. According to Coase (1937), market coordination is sometimes internalised to the firm due to costs associated with using the price mechanisms. These costs arise during the negotiating and concluding of contracts related to exchange transactions that the agents are involved in. Transactions are undertaken within firm boundaries when the costs of transactions in the market exceed those undertaken within a firm.

Transaction costs economics elaborates further on these basic Coasian insights. The main proponent of transaction cost economics is Oliver Williamson (Williamson 1975, 1985; see also 1991 and 1999). Williamson takes transactions across technologically separable stages of production along the value chain as his unit of analysis, and focuses on the economizing of various costs associated with such transactions. His main point is that different attributes of transactions give rise to different forms of coordination, or what he calls governance structures. In his earlier work, these governance structures include hierarchies and markets. The former refers to the internalisation of transactions within the boundaries of a firm while the latter refers to transactions occurring over the market between firms (Williamson 1975).

Williamson (1985, 1991) identifies three different attributes of transactions that are pertinent to different governance structures, namely the frequency with which transactions occur, the uncertainty to which transactions are subject to, and the type and degree of asset specificity involved in supplying the good or service in question. Of these, uncertainty is related to asymmetric information amongst economic agents, bounded rationality and the occurrence of opportunism. Asset specificity refers to specificities of the technology involved in a transaction in terms of site specificity, physical asset specificity, human asset specificity, and dedicated assets. The conclusion is that hierarchies are preferred when transactions are frequent, uncertainty and asset specificity is high – and hence transaction costs are high – while markets are preferred under the opposite conditions. He also acknowledges the existence of hybrid governance structures due to various trade-offs between different levels of these attributes of transactions. A joint venture is one example of such as hybrid structure, the viability of which increases with asset specificity as the bilateral dependency between firms grows, and coordinated adaptation to the environment is called for (Williamson 1991).

As should be clear from the foregoing discussion, transaction cost economics is mostly about the determinants of the degree of vertical integration of firms – or the decision whether to ‘make or buy R&D’. The discussion of hybrid governance structures, such as joint ventures, extends the framework towards including ‘co-make R&D’ or ‘co-buy R&D’. Other types of extensions have also been proposed, although these all remain loyal to the core idea of transaction cost economising behaviour (see Williamson (1999) for a discussion). Reference can also be made to incomplete contracting theory, in so far as a strategic alliance might be considered as a means to reduce the hazards of incomplete contracts typical to technologies characterised by high asset specificity. In these circumstances a full specification of all the actions of all collaborative partners in every contingency is impossible.[1]

While transaction cost economics offers a strong focusing device for analysing economic coordination in general, this framework has found limited applicability for understanding the specificities of strategic R&D alliances. As also noted by Vonortas (1997), a primary limitation is the overly focus on vertical rather than horizontal relationships between firms due to the sharp distinction made between hierarchies and markets. Hybrid forms of governance structures, between hierarchies and markets, can be taken to cover vertical strategic R&D alliances involving suppliers and component subcontractors in so far as the minimising of transaction costs is the underlying rationale. However, it is doubtful whether such vertical relationships between firms might fulfil the requirements of reciprocity that characterise strategic R&D alliances.

A more fundamental critique of this framework is the ignorance of the treatment of the complexities and dynamics of technological change and innovation. Antonelli & Quéré (2003) agree that transaction cost economising is of core concern to firms, but make the point that technological change and innovation as a process denies the purpose of economizing in any meaningful sense. This is because technological change and innovation is inherently wasteful as it involves trials and errors, experimentation, serendipity and related uncertainty. The nature of knowledge underlying such processes is typically tacit and complex, whereby it is difficult to articulate let alone contract and transact (compare with Dosi (1988)).

Nooteboom (1999) goes further by pointing to a conflict between the assumed association between high asset specificity, greater uncertainty, and hierarchies on the one hand, and on the other hand the factual observation that firms in dynamic, technologically complex and variable environments depend heavily on external knowledge during innovation (see Freeman (1991); Palmberg (2003) and the references therein). Hence, and in conclusion,

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[1] The relationships between transaction cost economics and incomplete contract theory is discussed at greater length in Caloghirou et al. (2003).

one might indeed agree with Williamson (1985, p.143) on the limitations of transaction cost economics: *"the study of economic organisation in a regime of rapid innovation pose much more difficult issues than those addressed here"*. Such limitations appear to diminish the applicability of transaction cost economics to the analysis of strategic R&D alliances especially in the ICT sector as a dynamic and technologically complex environment.

2.3 Strategic management and complementary assets

Following the increasing attention given to the complexities and dynamics of technological change and innovation, the fundamental insights of Oliver Williamson have been elaborated upon further from various viewpoints. One such viewpoint is provided by the strategic management scholar David Teece, which appears to be especially useful in this context (see Teece (1984), (1986) and (1992)). As noted by Lemola (1994), one might identify two generations of theorizing around these issues in the writings of Teece. In earlier papers the focus remains on 'make R&D in hierarchies' or 'buy R&D over the market' situations in line with transaction cost economics, although the dynamisms and complexities of technological change and innovation are better accounted for (Teece (1984,1986)). In later papers the analysis is extended further to also incorporate hybrid governance structures, such as strategic R&D alliances of both vertical and horizontal nature (see Teece (1992)).

The point of departure in Teece (1984) is dissatisfaction with the treatment of technological change and innovation in mainstream economics. Teece (1984) integrates technological change and innovation into the analysis by focusing on uncertainty and asset specificity. His initial theoretical framework caters to situations when firms face a choice between internalising their R&D into hierarchies or outsourcing it to suppliers and other types of collaborative partners. Such situations foremost arise in the context of systemic innovations, when firms often depend on complementary external knowledge. He approaches uncertainty and asset specificity through the concepts appropriability regime and complementary assets as the fundamental determinants of the choice of coordination structures related to the organisation of R&D.

An appropriability regime refers to the environmental factors, excluding firm and market structure, that govern an innovator's ability to capture the profits generated by innovation. These factors include the system of intellectual property rights, the possibilities to uphold secrecy, the degree to which knowledge is inimitable or tacit etc. (see Levin et al. (1987) for a lengthier discussion). Complementary assets refer to assets that an innovator needs for the commercialisation of technologies and innovations, which often reside outside the boundaries of the innovating firm. Teece (1986) furthermore makes the distinction between generic, specialized and co-specialized complementary assets. Generic assets are general purpose and do not need to be tailored to the needs of the innovating firm. Specialized assets imply unilateral dependence between the firm and the asset, while co-specialized assets imply bilateral dependency.

In this framework the treatment of uncertainty and asset specificity is enriched through a discussion of the characteristics of different types of appropriability regimes and complementary assets, and their effects on the choice of governance structures. A further enrichment of transaction cost economics is the inclusion of the relationships between the coordination of R&D and the life cycles of technologies. Teece (1986) makes the distinction between pre-paradigmatic and paradigmatic stages of technological change and industry evolution, with reference to the concept of dominant design or an agreed upon 'standard' (compare with standardization in the ICT sector) upon which future incremental innovations are based (see Abernathy & Utterback (1975) for a seminal paper). The conclusion of this analysis is that the outsourcing of R&D is preferable during pre-paradigmatic phases of technological change, with the coexistence of different paths to innovation combined with weaker appropriability and high uncertainty. However, as a dominant design emerges, technologies mature and competition intensifies, appropriability issue become more important. The internalisation of complementary assets into hierarchies becomes more critical. This conclusion is especially evident the more specialised these complementary assets are, since the innovating firm otherwise risks loosing the economic returns of innovation to the holders of such assets.

The framework proposed by David Teece is broader in scope since it caters to 'make or buy R&D' situations vertically as well as horizontally with respect to value chains. The focus on R&D as a distinct activity also downplays the role of transaction cost economising behaviour. The extension towards incorporating hybrid governance structures is discussed especially in Teece (1992), based on the observation that reality rarely is compatible with extreme cases. Here the focus shifts to strategic R&D alliances as a specific form of coordination defined as *"...a bilateral relationship characterised by the commitment of two or more partner firms to reach a common goal, and which entails the pooling of specialized assets and capabilities"* (Teece 1992, p.189). Thus strategic R&D alliances differ from transactions across the markets since they, by definition, never can be unilateral and have only one firm on the receiving side in terms of knowledge assets. They differ from hierarchies since they do not include M&A to gain access to other firm's assets, even though they might resemble hierarchies if they are equity based and durable.

In Teece (1992) it is suggested that an R&D alliance is preferred under conditions of weaker appropriability if complementary assets are more specialised and competitors are better positioned vis-á-vis these complementary assets. Accordingly, the incentives to form strategic R&D alliances decreases with the maturity of technologies, as appropriability regimes become stronger and complementary assets become less generic. Strategic R&D alliances are often superior when technology is new and uncertainty is high, as they facilitate the flexible handling of the related contingencies. When an industry reaches maturity with respect to technological change, the internalisation of R&D into hierarchies is a better strategy. Moreover, increasing alliance activity might be interpreted as a 'first step' towards such consolidation (compare with Cainarca et al. (1992)).

2.4 The resource-based view of the firm

The discussion of complementary assets draws attention to the absorption and appropriation of knowledge embedded in these assets. Accordingly, the third theoretical framework, labelled the resource-based view of the firm, has found relevance as a complementary and partly overlapping one. This framework is less of a coherent theory than a collection of likeminded contributions that share certain basic assumptions. Nonetheless, the general insights of these contributions do highlight important additional issues related to the motivation behind the formation of alliances, and to their stability and success over time.

According to Foss (1997) the resource-based view of the firm shares two fundamental assumptions of relevance also in this context, namely that (i.) there are systematic differences across firms in the extent to which they control resources necessary for innovation, and (ii.) that these differences remain relatively stable over time. Both of these assumptions have their origin in the seminal contributions on the growth of firms by Edith Penrose (Penrose 1959). She introduced the notion of 'bundles of resources' that underlie the sources of sustained firm performance, constituting of a mix of tangible and intangible assets that a firm possesses.[2] Penrose also makes the important distinction between these bundles of resources and the 'services that they can render'. She suggests that similar resources used for similar purposes in different organisational settings provide different types of outcomes.

Among others Nelson & Winter (1982), Rumelt (1984), Wernerfelt (1984), Dierickx & Cool (1989), and more recently Prahaland & Hamel (1990), Peteraf (1993), Teece et al. (1992), and Kogut & Zander (1992) have refined further these basic Penrosian insights (see Foss (1997) for a reader). One outcome of these contributions is some agreement within this literature on the criteria that distinguish resources that are truly critical for firms to access and control, and hence explain performance heterogeneity. Peteraf (1993) offers a synthesis by identifying four such criteria. The first criterion is that such resources should be unique, rare and firm specific, or heterogeneous across firms. The second criterion is

[2] The term 'resources' is in this context often used as synonymous to 'competences', 'capabilities', or more recently 'core competences'. The former might be considered to include both tangible and intangible assets, while the latter ones usually primarily refer to intangible assets.

that they must be difficult to imitate by competitors. The third is that there must be imperfect competition for their access as their value otherwise would be offset by the costs of acquiring them. The fourth criterion is that the resources must be imperfectly mobile to secure their cumulative value to the firm. Such resources are typically non trade-able, they are highly tacit and often cannot be assigned a price in the market.

From the viewpoint of strategic R&D alliances an obvious viewpoint highlighted is the importance of complementarities between internal and external knowledge for innovation, since no one firm can control all the critical resources conforming to these criteria. The resource-based view thereby complements the discussion of complementary assets by pointing to the complexities of the processes whereby firms might access and absorb these. There is a burgeoning literature focusing especially on the conditions for the successful absorption of such external knowledge. The seminal contributions are Cohen & Levinthal (1989, 1990) in which absorptive capability is defined as *"the ability of a firm to recognise the value of new, external knowledge, assimilate it, and apply it to commercial aims"* (Cohen & Levinthal 1990, p.128).

Cohen & Levinthal (1990) propose that absorptive capability requirements are higher and more demanding in environments characterised by rich technological opportunities, generic, complex and tacit knowledge. Firms in such environments depend to a great extent on cumulative knowledge generated through R&D to engage in knowledge exchange, for example through strategic R&D alliances. This is elaborated on further by Lane & Lubatkin (1998) who measure the relationship between the success of a sample of strategic R&D alliances in the pharmaceuticals industry in terms of patenting, and the relative similarity of the knowledge base of the partner firms. They conclude that greater similarity between firms in accumulated R&D within similar technical fields is associated with greater success.

Another viewpoint provided by this literature is the emphasis on the cumulativeness and tacit nature of knowledge (see especially Nelson & Winter (1982)). Specifically, the criterion of imperfectly mobile resources underlines that resources critical to firms are intertwined with their organizational setting. This criterion is especially relevant in high-technology industries, such as the ICT sector, where critical resources mostly relate to the mastering of complex technologies. Accordingly, a strategic R&D alliance might also be considered as an institutional structure to coordinate inter-organisational learning – or a 'learning alliance' – with the prime objective of seeking to gain access to, and comprehension of, the cumulative and tacit knowledge base of other firms. This theoretical framework thus differs from those discussed above, since issues such as trust, reciprocity and long-term relationships amongst alliance partners emerge to the forefront.

This viewpoint on strategic R&D alliances also links the discussion to the concept of social capital, which might be defined as social networks of trust and the normative rules and mutual expectations that underlie these networks (see e.g. Ruuskanen 2001). Strategic R&D alliances can therefore also be considered as a one type of social capital building, whereby social capital might contribute to the stability and success of alliances, and ultimately to the performance of firms (Vanhaverbeke et al. 2001).

2.5 Industrial organisation and the welfare effects of R&D alliances

The mounting evidence on both collaboration and competition between firms in R&D intensive industries has also recently been the subject of intense interest in the industrial organisation literature. This literature has focused on resource allocation and welfare effects of strategic R&D alliances as a part of a broader concern over market failures related to over- or under-investment in R&D (Hagedoorn et al. 2000). The specific issue dealt with concern the effects of these ventures on R&D levels and production output under various conditions of collaboration and competition between firms in highly formalised game-theoretic models. In this literature, strategic R&D alliances might be considered as the resolution of market failure by competing firms in an industry (Vonortas 1997).

Some of the seminal contributions in this tradition include Spence (1984), Katz (1986), and d'Aspremont & Jacquemin (1988). In these papers the models are cast in terms of a two-stage game. In the first stage two identical firms undertake collaborative R&D leading to reduction in unit costs, while they are competitors with homogenous products in their downstream markets in the second stage. Their focus is on comparisons of the magnitude of cost-reducing technical advances achieved when firms conduct R&D competitively versus cooperatively in the presence of spillovers.

Following these seminal contributions, there is an ever-expanding literature elaborating further on this game-theoretic set-up by relaxing some of the assumptions in the earlier models. For example, de Bondt et al. (1992) extend the assumption of duopolistic competition to cover oligopolistic competition with different numbers of rival firms. Suzumura (1992) and Kamien et al. (1992) also incorporate different types of cooperative R&D by the degree to which spillovers are generated. A further extension is found in Vonortas (1994) who incorporates different types of R&D by differentiating between imperfectly appropriable generic R&D and firm-specific R&D. Katsoulacos & Ulph (1998) enrich this analysis by incorporating endogenous spillovers arising both in the absence of a R&D joint venture, and when the venture has been formed, while criticising most previous studies on their assumption of exogenous spillovers. A broader review of this literature is found in Vonortas (1997).

Even though this literature contains several specific insights, some consistent findings appear to emerge which advance an understanding of strategic R&D joint ventures, and also provide important policy implications (compare with Hagedoorn et al. (2000)). First of all, it provides theoretical proof that situations of competition and collaboration can correct market failures in R&D and thus advance welfare. Secondly, it seems that the extent of knowledge spillovers is the key determinant for the degree to which such welfare effects arise. In the absence of spillovers the market seems to do better compared with collaboration through alliances, while the reverse seems to be the case in the presence of spillovers. Moreover, such spillovers induce firms to undertake R&D of highly inappropriable nature, as suggested also in studies of the case of SEMATCH joint venture in the US (see Irwin & Klenow (1996)).

Nonetheless, one might also be critical of this literature. As of yet it seems that it is highly theoretical, while empirical testing has been limited (Vonortas 1997). The literature appears to be overly focused on one specific type of strategic R&D alliances, namely R&D joint ventures where the interest of two or more firms is combined into a jointly owned unit through equity investments. The specificities of looser types of non-equity based alliances are not accounted for, for example related to how different types of agreements beyond R&D joint ventures affect the incentives to become engaged in joint R&D. Furthermore, the highly formalised and abstract reasoning of this literature implies that the tools provided appear as less relevant to analyse firm-level issues related to strategic R&D alliances, some of which were discussed above. Its primary application seems to be in broader macro-level policy analyses.

3 DEFINITIONS AND LITERATURE-BASED ALLIANCE COUNTING

3.1 A definition of strategic R&D alliances

As suggested above, and with reference to Teece (1992), a strategic R&D alliance might be defined as *"...a bilateral relationship characterised by the commitment of two or more partners to reach a common goal, and which entails the pooling of specialized assets and capabilities"* (Teece 1992, p.189). However, beyond this relatively loose and general definition there are many different ways to classify alliances, and delineate what type of collaboration is included or excluded. For this reason, it makes sense to start of with a closer scrutiny of this general definition prior to a more detailed discussion of the different ways to distinguish between different types of alliances.[3]

The focus on *bilateral*, as opposed to unilateral, relationships in this definition is important. A unilateral relationship would imply that firm A acquires X from firm B. A bilateral relationship would imply furthermore that firm B acquires Y from firm A as a condition for making X available to firm A, and both parties understand that the transaction will be continued only if reciprocity is observed. Thus bilateralism implies that the alliance is designed on the basis of mutual gain of a similar kind, and reciprocity amongst the partner firms at least *ex ante*. Strategic R&D alliances can thereby be differentiated from pure and once-off exchange transactions, such as subcontracting and unilateral licensing agreements, in which the resource of the transaction is supplied by the selling firm to the buying firm in exchange for cash (Teece 1992). An additional important criterion is that the relationship relates to the exchange of knowledge assets.

The definition also focuses on *commitments* between firms, thereby suggesting that a strategic R&D alliance is based on a formal agreement, typically of longer-term nature. Indeed, a salient feature of strategic R&D alliances is that they are based on contractual and/or equity-based agreements stipulating the rules of the game, the obligations of the partners and possible sanctions in case of non-fulfilment of the obligations. The definition also excludes informal collaboration and other types of partnerships that are not directly based on contractual agreements, even though formal relationships often contains elements of informal collaboration and vice versa. Strategic R&D alliances identified through contractual agreements might thereby constitute the visible 'tip of the iceberg' of collaborative patterns in industry. According to Hagedoorn et al. (2000) very little is in fact known about the relationships between strategic R&D alliances and various other types of informal collaboration.

3 Please note that the words 'strategic R&D alliance' and 'R&D alliance' will be used as synonyms from here onwards.

A strategic alliance is often understood as a relationship between two partners, although Teece (1992) also acknowledged that they might involve *two or more* partners. Strategic R&D alliances might comprise of quite complex, multilateral networks spanning various institutional boundaries. Government-sponsored initiatives such as the Advanced Technology Program (ATP) and SEMATECH in the US are good examples of such complex networks involving multiple partners both in the public and private sector (Link 2002). They might also span industrial boundaries and technology fields, and might thus be characterised as diagonal rather than vertical or horizontal (Nooteboom 1999).

Finally, the reference to a *common goal* and the active *pooling of specialized assets and capabilities* underlines further the reciprocity involved in a strategic R&D alliance, and their long-term in nature. It also underlines that they involve knowledge-intensive assets and capabilities such as those related to R&D, and discussed at greater length in Teece (1992). Moreover, the pooling of such assets and capabilities implies that the relationship between partners in an alliance is a close one, although it falls short of a complete merger of firms. Strategic R&D alliances might thereby also be considered as an alternative to mergers and acquisitions (M&As) in the strategic orientation of firms seeking to gain access to assets of other firms.

3.2 A typologisation of strategic R&D alliances

There are at least two broader typologisations that might be applied to strategic R&D alliances (compare with Hagedoorn et al. (2000); see Sheth & Parvatiyar (1995) for an alternative typologisation). They can be typologised by the type of partners involved in the alliance, and by the degree of mutual control embedded in the structure of coordination – or the organisational interdependency between the partners. The typology by the type of partners is foremost descriptive, while the typology by organisational interdependency is also analytically important with more direct ties to the theoretical frameworks discussed above. This typologisation of strategic R&D alliances is presented in figure 2 below.

However, before proceeding to a closer discussion of the figure it should be emphasised that the different types of strategic R&D alliances not necessarily are mutually exclusive as an alliance typically covers many different types of agreements. Thus, an alliance might be a R&D joint venture combined with a minority holding. Likewise, a non equity-based alliance might be joint research pact combined with R&D contracts and cross-licensing. One might also identify large alliances containing elements of both equity and non equity-based alliances. Furthermore, each type of alliance by organisational interdependency might also comprise of different constellations of partners etc.

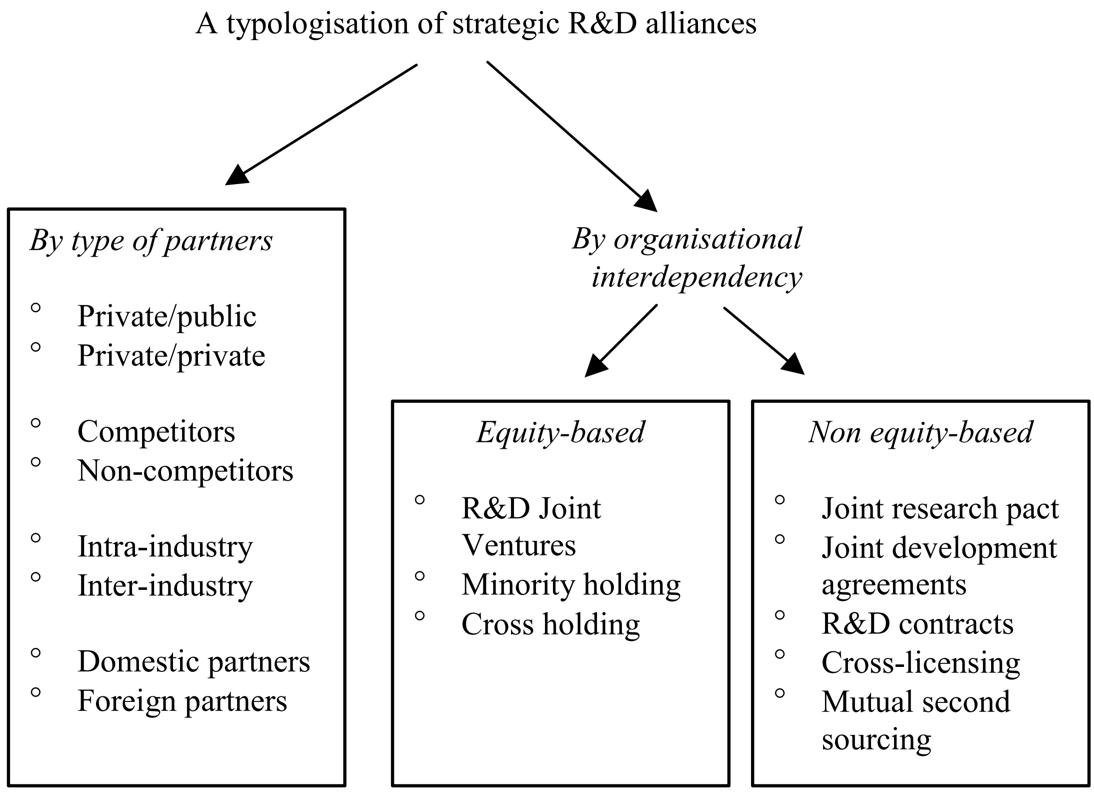


Figure 2. A typologisation of strategic R&D alliances

3.2.1 Partners in a R&D alliance

Starting off from the left hand side of the figure, a typology of alliances by the type of partners involved singles out such alliances where the partners span both the private and public sectors, and those that are confined to firms in industry. *Private/public* alliances typically cover alliances between publicly funded research organisations, or universities, and private firms. They have not been of widespread interest to especially technology policy analysis, mainly because they often involve public funding and thereby directly represent government intervention in the R&D and innovation processes of firms. Prominent examples of such alliances include SEMATECH and the Advanced Technology Program (ATP) in the US (Link 2002). Some of the frameworks programs commissioned by the EU might also be taken as examples of such alliances (see Luukkonen (2002) for lengthier discussion based on Finnish experiences). Nonetheless, private/private alliances account for the lion's share of all alliances. They will also be the focus of the subsequent analysis of strategic R&D alliances in the ICT sector.

Strategic R&D alliances in the private sector, between firms, might further be classified by whether the partners are *competitors* or not. Sheth & Parvatiyar (1995) refer to competitive alliances as those in which firms collaborate within R&D, while they remain competitors outside the alliance in the downstream markets. Such alliances are often among equals in terms of the resources and size of firms. They relate to achieving complementarities and economics of scope in R&D in the core businesses of the partner firms. In contrast, alliances between *non-competitors* tend to cover a broader range of activities beyond R&D, such as joint market development and marketing. Accordingly, they tend to be vertical rather than horizontal since they typically include suppliers or customer (Sheth & Parvatiyar 1995).

In addition, one might distinguish between strategic R&D alliances between firms within the *same industry*, and those between firms coming from *different industries*. In this context, inter-industry alliances have been referred to as diagonal alliances, since they might span value chains from different industries (Nooteboom 1999). Such diagonal alliances are of specific interest in the ICT sector due to the dynamics of overlapping technologies and the trend towards the convergence of computer and mobile telecom technologies due to digitalisation. According to Ali-Yrkkö (2001) such diagonal alliances usually aim at 'market making'; that is the development of new applications or product combinations with companies in third industries. Finally, strategic R&D alliances might be differentiated in terms of whether partners are *domestic or foreign* (or both). From the viewpoint of a small open economy, like Finland, alliances covering foreign partners might also be considered as a part of the internationalisation strategy of firms (see Duysters & Hagedoorn (1996) for a discussion).

3.2.2 Organisational interdependency between partners

The typologisation of strategic R&D alliances by the organisational dependency between partners is illustrated in the right hand side of figure 2 above. A rough distinction can be made between equity- and non equity-based alliances. *Equity-based* alliances involve equity investments, and thus reflect a tighter organisational interdependency between the partners. In contrast, *non equity-based* alliances reflect looser organisational interdependency since equity investment is involved. With an eye to the theoretical frameworks discussed above, equity-based strategic R&D alliances resemble hierarchies, or various hybrid governance structures as these are discussed in transaction cost economics. They have also been the prime focus of the industrial organisation literature. Non equity-based alliances fall outside these theoretical frameworks and appear more relevant to interpret in terms of complementary assets and the resource-based view of the firm.

Of equity-based alliances *R&D joint ventures* (RJVs) have received the most widespread interest.[4] RJVs and research corporations cover R&D alliances combining the interests of

[4] It should be noted that there are some terminological differences in the literature. The industrial organization literature tends to define strategic R&D alliances as R&D joint ventures, while the strategic man-

at least two separate partners, usually firms, into a jointly owned distinct unit over a longer period of time (Hagedoorn & Ekert 2002). The widespread interest shown towards RJVs stems from their proliferation as the most visible manifestation of strategic R&D alliances, even though there is evidence that looser types of non equity-based alliances have been increasing in importance more recently (Hagedoorn 2002). Especially economists have found it easier to come to grips with these types of alliances due to the association of RJVs with tight organisational interdependency, whereby they come conceptually close to hierarchies in terms of governance structures. (Vonortas 1997).

Other examples of equity-based alliances include *minority holding* and *cross holding.* A minority holding implies that one firm acquires a minor (less than 50 percent) interest in another firm through equity investments, while cross holding implies that two firms take a minority interest in each other at the same time. As a consequence, they fall short of the physical combination of the economic interests of two firms through a JRV, even though they are equity-based. Minority holdings and cross-holdings only cover alliances between firms in the private sector and fall short of a full merger due to the minority stakes. In practice, such holdings might often be embedded in other types of equity-based alliance structures.

When turning to the different types of non equity-based alliances, it is possible to distinguish between *joint research pacts, joint development agreements, R&D contracts,* and licensing as well as cross-licensing agreements. Research pacts and joint development agreements are characterised by tighter organisational interdependency. They are hence better covered by the definition of a strategic R&D alliance. They cover joint R&D of common interest to the partners for the development of new technologies or innovations. However, a joint research pact differs from a joint development agreement by the dedication also of shared tangible resources, for example in the form of a shared research lab. These types of alliances appear to come the closest to 'learning alliances' to facilitate inter-organisational learning and seek complementarities between the knowledge bases of the partners (compare with Vanhaverbeke et al. (2001)).

Licensing is usually of unilateral character since it implies the unilateral purchase of proprietary knowledge, and thereby falls outside the definition of strategic R&D alliances. Nonetheless, *cross licensing* agreements incorporate reciprocity that characterises strategic R&D alliances, since the partners in such an alliance exchange proprietary knowledge through licences to supplement their own R&D, or to avoid patenting or patent infringements (Hagedoorn 1989). Cross licensing is especially important in the ICT sector due to problems with overlapping patents and the principle of non-exclusive compulsory licensing

agement literature also includes looser types of non-equity based inter-firm collaboration in their definition of alliances (Vonortas 1997).

of patents to competing firms in the context of standardisation (Bekkers et al. 2002; Shapiro 2003). Finally, strategic R&D alliances might be *mutual second sourcing agreements*. Such agreements imply that firms exchange, or swap, component technology specifications, and thereby secures subcontracting in the longer term. This is the loosest type of R&D alliance, and resembles markets as a governance structure.

3.3 The CATI database

Empirical research on strategic R&D alliances has expanded rapidly throughout the 1990s within the various theoretical frameworks reviewed above. In this expanding empirical field one might identify two basic methodological approaches, namely the application of dedicated surveys covering a limited number of alliances in specific industries or countries, or the collection of certain basic data on alliances with a much broader scope from various publicly available sources. In addition, several case studies have been undertaken focusing in-depth on specific alliances, ranging from bilateral to multilateral one's such as the SEMATECH in the US or the EUREKA in the EU (see la Mothe & Link (2002) for a review).

Amongst the various broader approaches to data collection on strategic R&D alliances, one might mention the work undertaken by Albert Link and his colleagues based on the CORE database drawing on information contained in Federal Register in the US (Link 1996), the work undertaken by Nicholas Vonortas and his colleagues based on the NCRA-RJV database likewise drawing on the Federal Register (Vonortas 1997), the work drawing on the SDC database on strategic R&D alliances upheld by the Securities Data Company (Giuri et al. 2002), and the CATI database drawing on reviews of publicly available literature undertaken by John Hagedoorn and his colleagues at the Maastricht Economic Research Institute in Innovation and Technology (MERIT) at the University of Maastricht in Holland (see Hagedoorn et al. (2000) for a lengthier presentation of these databases).

The focus of the ensuing sections will be limited to the CATI database as the source of data for the analysis and reviews of strategic R&D alliances in the ICT sector. The CATI database is a relational database containing data on the year of formation, nature and technology content of some 15 000 alliances, and some basic data on the partners in an alliance. A strategic alliance is defined as a *"…collaborative agreements aligning common interests between, at the minimum, two independent industrial partners that are not connected through majority ownerships"* (Hagedoorn & van Ekert 2002, p.3). The database only covers alliances that contain some arrangements for mutual transfer of technology or joint R&D. Accordingly, the definition used in the CATI database is in line with the one suggested by Teece (1992) as discussed above. The data collected in the database also enables the typologisation of alliances in accordance with the typologies illustrated in figure 2. The only exception is that the database only covers private/private alliances between industrial firms.

Systematic data collection for the CATI database started in 1987 and has continued until present, complemented with sources from earlier years to extend the scope of the database back to the early 1960s. Presently, the database covers some forty years between the years 1960 and 2000 and it is updated every second year. The sources used for data collection include newspaper and journal articles, books dealing with the subject, and specialized journals that report on business events. Firms annual reports, the financial times industrial companies yearbooks, and Dun and Bradstreet's 'who owns whom' have been consulted for information about dissolved alliances. (Hagedoorn 2002).

Even though the database is relatively extensive in content and covers a very long time period, there are drawbacks and limitations. In general, only alliances publicly reported by the firms themselves are included in the database, whereby failures and the alliances of low profile firms probably are underreported. The literature reviewed, especially when going back in time, might report incompletely on alliances. The interest shown towards alliances might follow fads and trends independent of real developments in alliance formation. Incomplete reporting also implies that there is limited information on the termination of alliances. There is probably an Anglo-Saxian bias in the database against those countries and firms that are not covered by the Anglo-Saxian press as the main data source. It might also bias in favour of larger and well-known multinationals at the expense of smaller firms. However, despite these shortcomings – most of which are unsolvable in this type of extensive data gathering – the CATI database is presently the most extensive one available on strategic R&D alliances and does provide various research paths to follow.

4 STRATEGIC R&D ALLIANCES IN THE ICT SECTOR

4.1 The definition of ICT-related R&D alliances

The foregoing descriptive statistical analysis defines the ICT sector in terms of the technology fields within which firms have formed new strategic R&D alliances as reported in the CATI database. The CATI database covers ICT alliances within the fields of computer and related hardware, industrial automation, microelectronics components, software and telecom technologies. We will here focus on three of these technology fields that can be considered at the core of the ICT sector; namely microelectronics, software and telecom technologies.

Our focus on these technologies is motivated by the importance of the telecom industry to the Finnish ICT sector. In the CATI database the field of telecom covers all essential technologies constituting fixed or wireless (cellular) telecom systems. The inclusion of microprocessors in the definition of ICT used here is motivated by the fact that telecom equipment suppliers are major users of these components, which provide the brainpower of modern telecom systems. Telecom equipment suppliers are also major users of software technologies, especially since the digitalisation of wireless networks starting from the late 1980s. Software defines the user interface of telecom equipment by providing value-added applications, such as multi-media messaging (MMS) as the most recent one.

As suggested in the introduction, the foregoing analysis does not aspire to provide a detailed analysis of strategic R&D alliances in theses selected technology fields. Rather, the ambition is to introduce the CATI database in a Finnish context through analysis of broader trends, and thereby also complement the review of theoretical frameworks in section 2 and the definition of alliances in section 3 with empirical illustrations. The analysis also complements and updates previous CATI-based research to which reference is made when appropriate. Previous research has covered different time periods and technology fields, has addressed more specific research questions, and has sometimes also combined CATI with other databases. We have chosen to primarily refer to peer-reviewed articles published in international journals to secure the quality and reliability of our interpretations.

4.2 Distribution of R&D alliances by technology fields

The CATI database contains data on the year of formation of alliances, which enables an analysis of trends in alliance activity over time. Before proceeding to the core ICT sector as the focus of this paper, a general overview of broader trends in the ICT sector as a whole is motivated (figure 3).

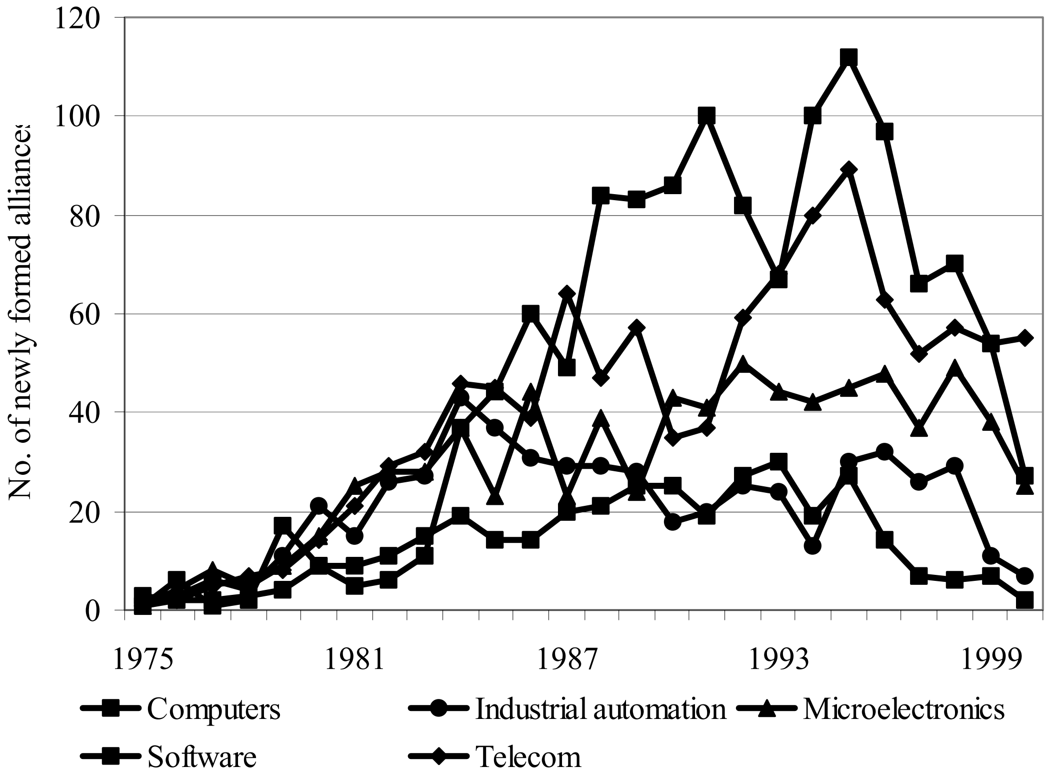


Figure 3. The growth of newly formed strategic R&D alliances in the ICT sector 1975-2000

Overall, there has been a relatively steady growth in the number of newly formed alliances even though the trend turns erratic after the mid 1980s. By and large, this is consistent with general trends in the growth in the number of alliances across all sectors covered by the CATI database (Hagedoorn 2002). Previous research also suggests that the proliferation of the European Communities (later the European Union) as a initiator, financier or coordinator of alliances through such programs as ESPRIT, RACE, BRITE and EUREKA in the field of ICT has played and important role in the European context throughout the 1980s and early 1990s (Hagedoorn & Schakenraad 1993). However, the late 1990s has witnessed a very clear decline in the number of alliances across all ICT technology fields, with the exception of telecom. This decline appears to reflect the general downturn in the ICT markets that we are presently witnessing.

Apart from these general trends there are interesting differences across the different technology fields. It is clear from the figure that the fields of telecom, microelectronics and software are the objects of the majority of all alliances, thereby motivating further the focus of this paper on these technology fields. The rise of software technologies as an important field of alliance activity during the late 1980s is especially clear. Moreover, the decline in the number of alliances formed within this field is less drastic during the early 1990s when compared with especially computers, industrial automation and telecom. Nonetheless, since the mid 1990s the decline in the number of newly formed software alliances has been especially rapid.

The peak in the late 1980s, and the subsequent temporary decline, in the number of newly formed alliances in the field of telecom technologies is also interesting. This pattern probably reflects the boom in standardisation of digital cellular systems, especially in Europe. This boom was spearheaded by the intensive phases of GSM standardization in the late 1980s prior to the inauguration of the service in the early 1990s. The so-called 'basket-model' applied in the GSM standardization led to the formation of several competing strategic R&D alliances and cross-licensing of intellectual property rights (IPRs) embedded in patents (Bekkers et al. 2002). These alliances were also necessary in order to secure interoperability of the different component technologies, even though the subsystem interfaces were fully specified in the GSM standard (Palmberg & Martikainen (2003)).

A new peak is recognisable around 1996, which coincides with the development of the Internet Protocol (IP-protocol) as a new complementary technology to be mastered by the telecom operators and equipment suppliers (Langlois & Robertson 1992; OECD 2000). It also coincides with the development of the GPRS standard as a platform on the path towards mobile packet data services and eventually the UMTS. After the mid 1990s the telecom field clearly show less fluctuation and decline when compared to the other fields. One reason might be that the size of alliances in this field has grown due to increasingly complex standards, whereby firms seek to gain access to complementary technologies through fewer but larger alliances. Moreover, especially software is increasingly embedded in telecom technologies whereby software alliances might be replaced by telecom alliances as time goes by.

On a general level the differences across the technology fields might also be interpreted in the light of alleged broader trends towards convergence in the ICT sector (see appendix 2 for major technological developments in the industry). Alliance activity in the different technology fields might be sequentially related since microelectronics technologies enable developments in the other fields, as suggested above. Likewise, developments in the fields of computers have direct consequences for developments in software and telecom.

Specifically, the 1980s marked the introduction of commercial microprocessors and Digital Signalling Processors (DSPs), thereby enabling the development of programmable devices, such as the PC. These developments are probably captured in the increase in microelectronics related alliances in the mid 1980s, followed by a subsequent rapid increase in alliances relate to computers, industrial automation and telecom as the major fields of applications. Thus, strategic R&D alliances might be considered as a facilitator of such technological convergence, as firms seek to secure access to complementary technologies and other assets from adjacent fields (compare with the discussion in Teece (1986)). Nonetheless, there is also research to suggest that the convergence between computers and telecom has not significantly altered the core technological competencies of large firms in the ICT sector as captured by their patenting profiles (Duysters & Hagedoorn 1998).

The very rapid increase in software alliances since the late 1980s could be related to development of standardized PC operating systems (most significantly MS-DOS, Macintosh, Windows), and the availability of simple software developing tools (e.g. Visual Basics). This standardization has led to the consolidation of the software industry and the dominance of a few large firms. This consolidation was most evident in the US in the early 1980s, where alliances between IBM, Microsoft and subsequently also Apple Computer Company dominated overall alliance activity (Hagedoorn et al. 2001). Nonetheless, the very sharp decline in the number of newly formed software alliances since the late 1990s is an interesting development worthy of further research.

Table 1. The distribution of R&D alliances across core ICT technology sub-fields

	1960-1989		1990-2000	
	Freq.	Percent	Freq.	Percent
Microprocessors				
Processors	54	5	110	6
Chips	161	14	229	12
Other generic components	13	1	32	2
Multi-tech microelectronics	94	8	64	3
Software				
Standard software	64	5	134	7
Professional software	271	23	581	31
Other miscallenous software	0	0	36	2
Multi-tech software	86	7	84	4
Telecom				
Public networks	10	1	12	1
Private networks and service	120	10	199	10
Cellular systems	40	3	76	4
Other telecom systems	186	16	142	7
Multi-tech telecom	73	6	196	11
Total	1172	100	1895	100

The technology fields in the CATI database can be disaggregated further into sub-field that we selected for closer analysis. In order to capture changes over time, we divide the data into the two periods 1960-1980 and 1990-2000 (table 1). Accordingly, we seek to contrast the watershed developments related to the introduction of commercial microprocessors and DSPs in the 1980s, and the subsequent developments related to the IP protocol, as well as to the standardisation of digital cellular systems in the 1990s, such as the GSM, GPRS and

UMTS. The division of the data into these periods also divides the number of observations into two relatively equally large datasets, and thereby better facilitates comparisons.

A significant share of all alliances in the ICT technology fields relate to various professional customised software. Moreover, professional software has become an increasingly important field over time in the alliance activity of firms and largely accounts for the growth of software alliances illustrated in figure 3 above. Other significant fields of alliance activity are chips, private networks and related services, and other miscellaneous telecom systems (transmission systems, telematics, email systems etc.). Interestingly, the field of cellular systems appears to have been subject to relatively less alliance activity although a closer inspection of the data reveals a strong upward trend since 1999 in the number of newly formed alliances. This upward trend coincides with the development of third and forth generation mobile standards on top of the GSM.

Altogether 21 percent of all alliances are classified to many different technology subfields. Again a closer inspection of the data reveals an exceptionally rapid growth of these types of alliances during the 1990s in the field of telecom. Thus, it seems that telecom alliances are becoming increasingly complex over time in terms of the technology fields that they cover. This appears to be in line with the increasing complexity of standards, as noted above.

4.3 Types of R&D alliances by partners

It is possible to typologise alliances in the CATI database by differences in the organisational interdependency between the partners in the alliance by the type of contractual agreement that ties them together (compare with the typology in figure 2). In terms of partners, one straightforward viewpoint is the mean number of partners participating in an alliance as an indicator of its size.

The size of R&D alliances by the number of partners

The mean number of partners to an alliance gives a an indication of the size of alliances and changes over time in different technology fields, even though this indicator should be interpreted with care in the early 1980s due to small number of newly formed alliances – for this reason we omitted the 1970s from the figure (figure 4).

The overall mean number of partners to an alliance across the core ICT technology fields is 2.25 while the median is 2. The distribution is thus highly skewed to the left with a few very large alliances in the right-hand tail of the distribution. Overall there is no clear trend in the mean size of alliances over time, even though there is greater variation in the size of alliances in the 1980s when compared to the 1990s. The peaks in the early 1980s in the

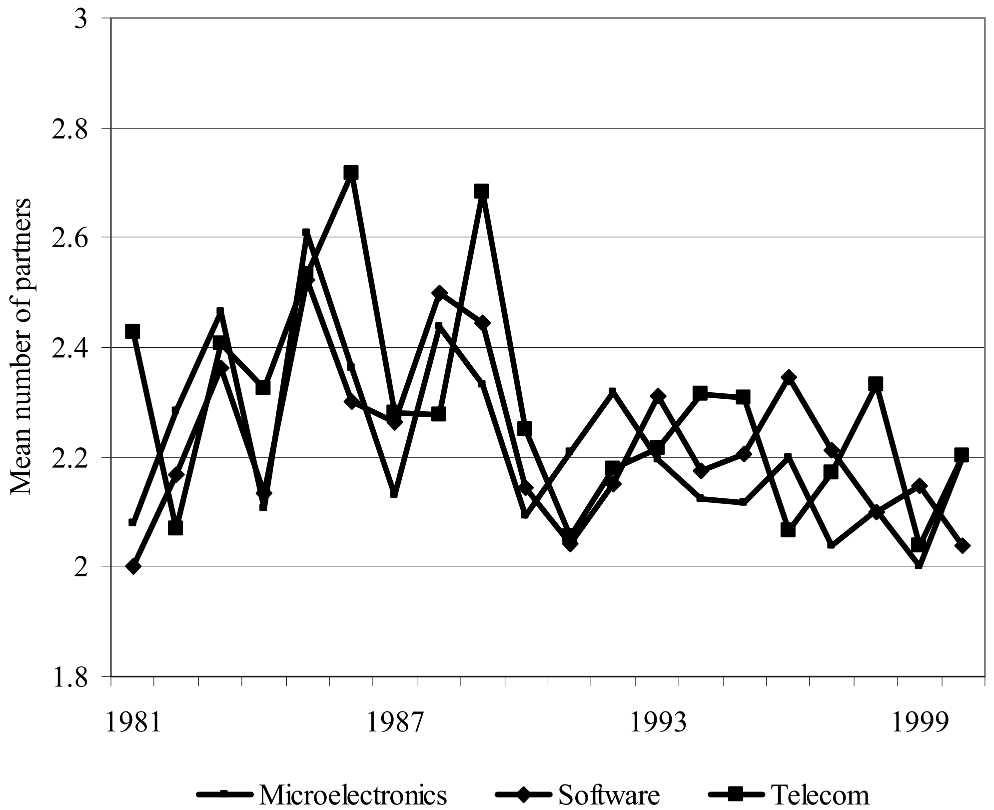


Figure 4. The size of R&D alliances by mean number of partners across the core ICT technology fields 1975-2000

field of software, and in the mid and late 1980s in all fields are interesting. A closer inspection of the data reveals that these peaks foremost are accounted for by the increase in the mean size of alliances in the fields of multi-tech software in the early 1980s, multi-tech telecom in the mid 1980s, and cellular systems in the late 1980s.

When the data is disaggregated by technology sub-fields and divided into the two periods 1960-1989 and 1990-2000 some interesting differences emerge. The lesser variation in the size of alliances is confirmed through a clear drop in the standard deviation in the 1990s when compared to the earlier period. Although the differences in the size of alliances across the technology sub-fields are small, the largest alliances are found in the fields of standard software and telecom-related technologies. Especially cellular systems technologies are characterised by larger alliances in both time periods. Apparently firms face a greater need to seek technological complementarities from multiple partners in this field – this is consistent with the above-suggested trends towards increasingly complex standards involving an increasing number of firms (compare with Teece (1986) and Mowery et al. (1998)).

Table 2. The size of R&D alliances by the mean number of partners in the core ICT sub-technologies 1960-1989 and 1990-2000

	1960-1989		1990-2000	
	Mean	Std. Dev.	Mean	Std. Dev.
All	2.35	1.36	2.18	0.73
Microelectronics				
Processors	2.52	1.83	2.21	0.86
Chips	2.25	1.00	2.13	0.50
Other generic components	2.08	0.28	2.12	0.34
Multi-tech microelectronics	2.23	1.27	2.09	0.39
Software				
Standard software	3.34	3.09	2.23	0.81
Professional software	2.19	0.90	2.15	0.61
Other miscallenous software	0.00	0.00	2.14	0.42
Multi-tech software	2.21	0.84	2.33	1.40
Telecom				
Public networks	2.40	0.70	2.08	0.29
Private networks and services	2.50	1.88	2.19	0.63
Cellular systems	2.45	0.88	2.47	1.64
Other telecom systems	2.28	0.86	2.12	0.40
Multi-tech telecom	2.47	1.36	2.19	0.66

However, the larger and growing size of alliances in these fields also raise a more general issue related to the nature of competition. Some recent CATI-based research focuses on the relationships between structures of alliance networks and the performance of firms under the assumption that alliances groupings, or constellations of alliances between firms, rather than individual firms compete (see especially Duysters & Vanhaverbeke (1996) and Duysters et al. (2003)). Thus the analytical focus should shift from dyads of bilateral alliances to alliance grouping consisting of interlinked multilateral alliances. Specifically, with a point of departure in the resource-based view of the firm Vanhaverbeke et al. (2001) show that the development of in-house competencies and extensive alliance networking are complementary strategies which both contribute to the technological performance of firms. However, these two strategies appear to be substitutes vis-à-vis performance in cases where firms are excessively engaged in both strategies.

The position of firms and countries in R&D alliance networks

Another viewpoint is to examine the ranking of firms and countries by the number of alliance that they have been involved in. This reveals some aspects of the changing position of firms and countries in global networks of strategic R&D alliances, even though a full-fledged network analysis is outside the scope of this paper (compare with Hagedoorn & Schakenraad (1992) and Duysters & Hagedoorn (1996)). The logic here is that a firm ranking high by the number of alliances it has been involved in reflects superiority in terms of technological assets. Likewise, a country ranking high by the number of alliances reflects the strength of this country to provide a suitable environment for firms engaged in collaborative R&D.[5]

Obviously, a high ranking in the list will also reflect size differences between firms and countries, since large firms and countries tend to be more diversified and have greater R&D resources. Moreover, large firms probably have better prerequisites to form and manage multiple alliances. It should also be noted that it is not possible to take into account differences in the quality and economic significance of alliances.

Table 3. Ranking of firms by the number of newly formed R&D alliances in the field of microelectronics

1960-1989		1990-2000	
Firms	Freq.	Firms	Freq.
SIEMENS	28	IBM	44
INTEL	27	TOSHIBA	42
TEXAS INST.	23	MOTOROLA	37
AMD	20	INTEL	35
PHILIPS	19	TEXAS INST.	30
THOMSON	19	SIEMENS	22
NAT-SEMI	19	NEC	20
FUJITSU	18	AMD	19
MOTOROLA	18	H-P	18
TOSHIBA	17	HITACHI	18
FAIRCHLD	13	FUJITSU	15
NEC	13	SGS/THOM	13
LSILOGIC	11	VLSI	13
AT&T	10	SUN-MICR	12
OLIVETTI	10	PHILIPS	11
H-P	10	MITSUBIS	11
GE	10	SAMSUNG	10
No. of firms	258		354
Mean	2.85		2.62
Std. Dev.	4.29		5.19

Table 3 presents the top 17 firms in the field of microelectronics during 1960-1989 and 1990-2000. As a general insight it should be noted that most firms are traditional suppliers of microprocessors or miscellaneous electronics equipment, while software and telecom firms are relatively absent. The top of the list is dominated by the large US firms Intel, Texas Instruments and Motorola (which is also in the mobile telephony business), even though Siemens also has been strongly present. Other important firms are the Japanese

[5] Please note that inter-country alliances between two firms from the same country are not excluded in the ranking of countries.

electronics conglomerates, most notably NEC, Toshiba, NEC, Hitachi, and Fujitsu. These firms have remained at the top of the list throughout the 1990s, although some shifts are especially noteworthy. Siemens has partly lost its dominating position, while the position of especially IBM and also Toshiba has been significantly strengthened. However, by and large, changes over time are relatively slight, even though new firms have entered the networks. There is only a slight increase over time in the mean and standard deviation of the number of new alliances formed by the firms.

The ranking of countries by the number of alliances, essentially confirms what was noted above (table 3). The dominance of the US is very clear and points to the fact that also smaller US firms have been frequent alliance partners. Japan ranks second in both time periods, although far behind the US by the number of newly formed alliances. This domination of the US and Japan is also captured in an increase over time in the mean and standard deviation of the number of newly formed alliances. More surprising is the relatively strong position of Holland in this list, although this is largely explainable by the alliance activity of Phillips. The position of South Korea and Taiwan seems to be strengthening, even though these countries do not host any of the top firms in terms of alliance activity in

Table 4. Ranking of countries by the number of newly formed R&D alliances in the field of microelectronics

1960-1989		1990-2000	
Countries	Freq.	Countries	Freq.
US	394	US	549
JAPAN	131	JAPAN	167
GERMANY	44	GERMANY	52
FRANCE	39	HOLLAND	38
HOLLAND	35	UK	29
UK	34	SOUTH KOREA	28
ITALY	21	FRANCE	21
SOUTH KOREA	10	TAIWAN	13
SWITZERLAND	5	CANADA	5
SWEDEN	4	SINGAPORE	5
TAIWAN	3	CHINA	4
CANADA	3	AUSTRIA	3
FINLAND	2	SWEDEN	3
NORWAY	2	ISRAEL	3
SPAIN	2	SWITZERLAND	2
ISRAEL	1	LUXEMBURG	1
BELGIUM	1	ITALY	1
No. of countries	22		20
Mean	33.45		46.35
Std. Dev.	85.70		124.1

microelectronics. Noticeable is also the presence of Finland during 1960-1989 – this relates to early phases of the GSM prior to Nokias outsourcing of microprocessor production to large firms abroad (Palmberg & Martikainen 2003). Finally, it should be noted that China also has entered the list during the 1990s.

When turning to the field of software (table 5), a striking feature is the very dominating position of a few large US computer and software firms, namely IBM, Microsoft, and Sun-Microsystems. Moreover, these firms appear to have been partners to a significant share of the increase in newly formed software alliances in the 1990s, as indicated by a doubling in the number of their alliances. This is also reflected in the rising means and standard deviations shown in the table. The strengthened position of the US computer equipment firms Hewlett-Packard, Oracle and the microelectronics supplier Intel, is also noteworthy. These developments highlight the superior position of US firms in software technologies. They appear to be consistent with the suggestion above that the standardisation of operating systems restructured the industry, and reshuffled the position of firms in favour of US firms. Specifically, the standardisation of the Windows operating system has surely contributed to the dominating position of Microsoft.

Table 5. Ranking of firms by the number of newly formed R&D alliances in the field of software

1960-1989		1990-2000	
Firms	Freq.	Firms	Freq.
IBM	40	MICROSFT	89
OLIVETTI	27	IBM	87
SUN-MICR	21	H-P	79
AT&T	21	SUN-MICR	53
MICROSFT	20	ORACLE	41
DEC	20	APPLE	36
PHILIPS	20	NOVELL	34
H-P	20	INTEL	33
VOLMAC	19	DEC	33
BULL	18	NETSCAPE	20
SIEMENS	15	COMPAQ	18
ICL	13	SILICONG	18
CDC	11	SAP	15
FUJITSU	11	TEXAS INST.	15
TANDEM	11	USL	14
LOTUS	10	ADOBE	13
RAET	9	MOTOROLA	13
No. of firms	444		781
Mean	2.25		2.33
Std. Dev.	3.70		6.47

Apart from this concentration at the top of the list, there have also been some interesting internal shifts in the position of firms. The ranking list reflects the demise of such firms as DEC, Phillips and Bull, which were major minicomputer manufacturers with their own proprietary hardware and software that was incompatible with the Windows operating system. Most significantly however, the position of the US operator AT&T, Siemens, the Japanese firm ICL and especially the Iltalian firm Olivetti has weakened significantly. The position of Japanese firms is much weaker in software when compared to microelectronics. Apart from Siemens and Motorola, the list does not include any other major telecommunications equipment producer. AT&T is the exception, and its position as an alliance partner has diminished significantly after its break-up in 1984. One major entrant as an alliance partner into this field in the 1990s are the US firms Netscape and Cisco, which presently also is a key player as a suppliers of components to the telecom industry.

Table 6. Ranking of countries by the number of newly formed R&D alliances in the field of software

1960-1989		1990-2000	
Countries	Freq.	Countries	Freq.
US	511	US	1466
HOLLAND	158	GERMANY	76
UK	78	JAPAN	70
JAPAN	63	UK	58
FRANCE	55	HOLLAND	32
ITALY	43	CANADA	25
GERMANY	41	FRANCE	24
BELGIUM	20	ITALY	11
SWEDEN	4	BELGIUM	9
AUSTRAL	4	FINLAND	7
LUXEMBURG	3	SWEDEN	5
CANADA	3	SINGAPORE	4
ISRAEL	2	INDIA	3
UNKNOWN	2	SOUTH KOREA	3
USSR	2	DENMARK	2
SOUTH KOREA	2	IRELAND	2
NORWAY	2	AUSTRAL	2
No. of countries	21		29
Mean	47.48		62.72
Std. Dev.	113.10		270.69

Again the country ranking reveals very clearly the dominance of the US in the alliance activity of firms in software (table 6). This position of the US has also strengthened significantly over time, even beyond the larger firms such as IBM, Microsoft and Sun-Microsystems. This is also reflected in a rise in the mean number of alliances, and especially in the very sharp rise in the standard deviation as an indicator of the wide dispersion between US- based alliances versus the position of other countries. These other countries, such as the UK, Japan, Germany and France, fall far behind. Nonetheless, the relatively strong position of these countries is surprising since it does not show up in the firm ranking. The decline in the position of Italy probably relates to the demise of Olivetti. Interestingly, Sweden ranks among these top 20 countries in both periods even though the number of alliances is small. Likewise, the position of Finland has clearly strengthened in the 1990s, primarily due to the GSM related software developments at Nokia throughout the 1990s (Palmberg & Martikainen 2003). Noticeable is also the presence of India and South Korea on the list in the 1990s.

Table 7. Ranking of firms by the number of newly formed R&D alliances in the field of telecom

1960-1989		1990-2000	
Firms	Freq.	Countries	Freq.
IBM	36	ERICSSON	49
AT&T	31	IBM	42
SIEMENS	25	AT&T	39
ERICSSON	25	SIEMENS	37
PHILIPS	19	CISCO	36
BT	17	MOTOROLA	34
OLIVETTI	15	H-P	27
FUJITSU	14	MICROSFT	26
NT	14	INTEL	25
PLESSEY	14	SUN-MICR	25
DEC	14	DEC	20
CTNE	13	ALCATEL	19
RACAL	13	NT	15
PTT-TEL	13	NOVELL	15
NTT	12	NOKIA	14
WANG	11	3COM	14
NYNEX	11	COMPAQ	14
No. of firms	363		605
Mean	2.82		2.29
Std. Dev.	4.10		4.76

A lesser degree of concentration at the top is evident in the field of telecom (table 7). IBM, AT&T, the Swedish telecom supplier Ericsson, and Siemens dominate the ranking list. Nonetheless, the 1990s has witnessed the entry of firms with their core focus outside telecom just below these four dominating firms, most noticeably Cisco, Microsoft and Intel. Accordingly, there appears to be an increasing interest of these firms to form telecom-based alliances, even though the alliance activity of telecom firms in the fields of microelectronics and software is less evident. A potential explanation is the introduction of the IP-protocol, which facilitates the convergence between computers and telecom. By and large, it seems that alliance activity in the field of telecom is relatively evenly dispersed across the firms compared with microelectronics and software. This is also reflected in the low standard deviation in both time periods.

Moreover, the position of especially Motorola and Nokia has strengthened significantly in the 1990s when compared to the 1980s. From a Finnish viewpoint the significant proliferation of Nokia as an alliance partner in the 1990s is particularly interesting. According to Bekkers et al. (2002) the rise of Motorola and Nokia in the ranking during the 1990s is foremost related to the large share of patents regarded as essential to the GSM standard that these possessed during the late 1980s and early 1990s. Especially Motorola was able to exercise direct influence on the structure of subsequent alliance networks through its aggressive IPR strategy, resulting in the strong position that is also evident in table 7 (see also Iversen (1999)). Bekkers et al. (2002) highlight the interrelationships between the distribution of IPRs, the structure of alliance networks and market shares, and concludes that IPR strategies can be an important part of the alliance strategies of firms.

Table 8. Ranking of countries by the number of newly formed R&D alliances in the field of telecom

1960-1989		1990-2000	
Countries	Freq.	Countries	Freq.
US	410	US	868
JAPAN	126	GERMANY	94
UK	95	JAPAN	84
FRANCE	75	SWEDEN	62
GERMANY	63	UK	47
HOLLAND	61	CANADA	46
ITALY	50	FRANCE	41
SWEDEN	33	HOLLAND	33
CANADA	29	FINLAND	18
SPAIN	18	ISRAEL	17
BELGIUM	9	CHINA	10
FINLAND	9	TAIWAN	9
AUSTRALIA	9	SWITZERLAND	6
SWITZERLAND	7	ITALY	6
DENMARK	5	COLOMBIA	4
TURKEY	4	AUSTRAL	4
UNKNOWN	3	SINGAPORE	4
No. of countries	29		36
Mean	35.34		38.47
Std. Dev.	79.11		144.22

The country rankings of alliances in the field of telecom also points to the strong position of the US even though its dominance is somewhat less striking. Likewise the mean remains stable over time, even though the strengthening position of the US shows up in a rising standard deviation over time. Beyond the US the role of European countries seems to be relatively more important in this field when compared to microelectronics and software. This is most likely primarily related to the active stance on pan-European standardization that many European operators and firms have taken throughout the 1980s and 1990s. The strong presence of Ericsson in telecom-related alliances is also reflected in the strong position of Sweden as a country, especially since 1990. Likewise, the alliance activities of Nokia have elevated Finland to a ninth position in this ranking during the 1990s. Noteworthy is also the strengthened positions of China and Taiwan, ranking just below Finland in the 1990s. Nonetheless, the South-East Asian countries are surprisingly absent with the exception of Singapore.

4.4 R&D alliances by organisational interdependency between partners

It was suggested that a typologisation of alliances by the organisational interdependency is analytically interesting since it ties directly to theoretical frameworks discussed above. In the CATI database alliances are classified by organisational interdependency according to

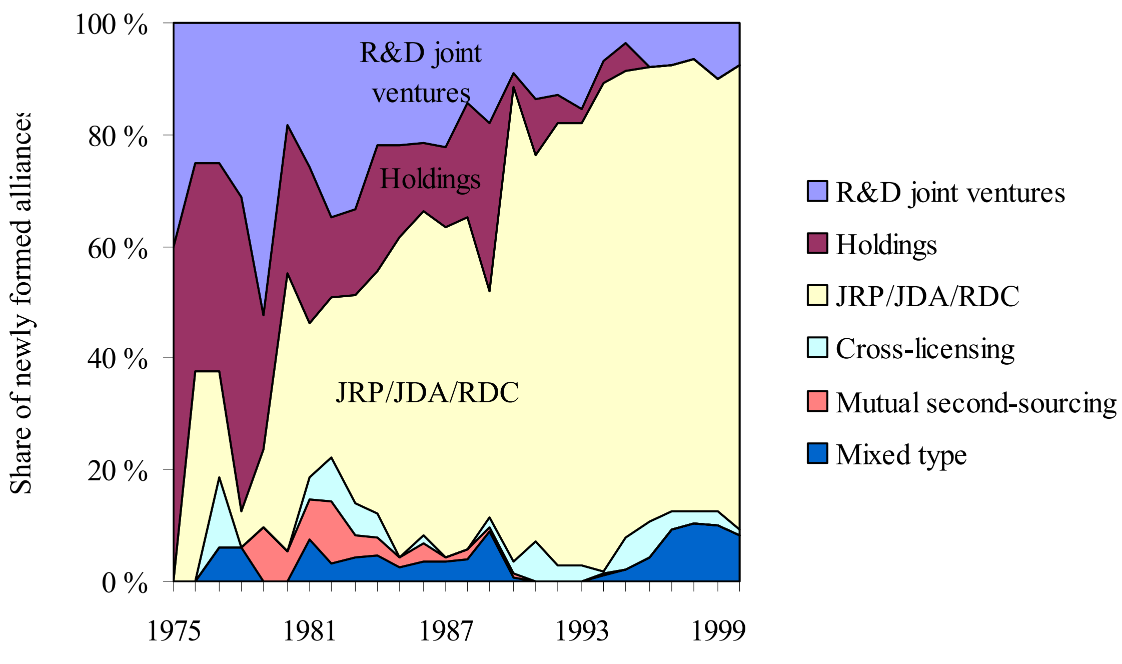


Figure 5. Contractual arrangement of R&D alliances in the ICT sector 1975-2000

the typologisation discussed in connection to figure 2 above. Again an overview of broader trends over time in the ICT sector is motivated. This is achieved by distinguishing between alliances in terms of the different types of equity, non-equity, and mixed contractual agreements (figure 5).

There is a very clear trend towards an increasing share of non-equity based alliances over equity based and mixed ones, as illustrated primarily through the rapid increase in the share of joint research pacts (JRPs) and development agreements (JDAs) since the early 1980s. Accordingly, alliances in the ICT sector are becoming increasingly looser over time by the organisational interdependency between partners to the alliances. In fact, the trend is similar for all alliances recorded in the CATI database (Hagedoorn 2002). This trend is especially evident in such high-tech sectors as ICT with over 1.5 times as many non-equity based alliances as the average across all other sectors covered by the CATI database. Interestingly, the share of equity-based alliances – primarily R&D joint ventures – is relatively higher in the more traditional sectors such as chemicals, engineering, food and beverages, and metal products (see also the discussion in Hagedoorn (1993)). A surprising result is the very low share of alliances involving mixed contractual arrangements.

Table 9. Contractual arrangement of R&D alliances across the core ICT technology fields (columns sum to 100 percent by technology fields)

	1960-1989		1990-2000	
	Freq.	Percent	Freq.	Percent
Microelectronics				
R&D joint ventures	62	19	43	10
Holdings	48	15	6	2
JRP/JDA/RDC	150	47	344	80
Cross-licensing	20	6	22	5
Mutual second-sourcing	34	11	2	0
Mixed type	8	2	14	3
Software				
R&D joint ventures	79	19	65	8
Holdings	115	27	32	4
JRP/JDA/RDC	222	53	686	82
Cross-licensing	1	0	27	3
Mutual second-sourcing	0	0	0	0
Mixed type	4	1	22	3
Telecom				
R&D joint ventures	144	34	63	10
Holdings	94	22	16	2
JRP/JDA/RDC	180	42	513	82
Cross-licensing	2	0	18	3
Mutual second-sourcing	0	0	0	0
Mixed type	9	2	17	3

When the same distinction is applied to the different ICT technology sub-fields and changes over time, the rapid increase and prevalence of non-equity based alliances over equity and mixed ones is underlined further. Prior to the 1990s around 45 percent of all alliances in the three fields of microelectronics, software and telecom are either joint research pacts (JRPs), joint development agreements (JDAs) or R&D contracts (RDC). In the 1990s the share has risen to 80 percent across all technology fields. The share of cross-licensing and mutual second-sourcing agreements is negligible. Nonetheless, the share of equity-based agreements, namely R&D joint ventures (RJVs) show greater variation across the fields.

Apparently, relatively tighter organisational interdependency occurs in the field of telecom as indicated by the higher share of RJVs, even though this share also declines in the 1990s. When disaggregating the data further to the technology sub-field level, the share of RJVs is the highest (around 20 percent) in mobile telephony in both time periods. This could perhaps be explained by the paramount importance of standards in this field, which might call for tighter governance structures to facilitate close collaboration and interactive learning in technologically complex technologies, even though firms subsequently compete in the markets created by the standards. Another interesting observation from a disaggregated viewpoint is that multi-tech alliances, spanning many technology sub-fields, are also characterised by a higher share of equity-based RJVs.

5 A SUMMARISING DISCUSSION

5.1 Theoretical observations

The global proliferation since the 1980s of strategic R&D alliances touches on the core theoretical issue of how firms coordinate their activities through different types of governance structure. Transaction cost economics, as a very influential framework in this context, suggests that inter-firm collaboration through strategic R&D alliances is a hybrid form of governance structure in between hierarchies (in-house R&D) and markets (outsourced R&D) as the superior alternatives in most cases. Specifically, firms might coordinate their activities through an alliance for the completion of a specific type of R&D task by aligning their competencies and other resources under joint ownership. These hybrid governance structures reduce transaction costs by incorporating a higher degree of reciprocity between contracting partners in cases were the technologies subject to the transaction are complex and uncertain, and joint adaptation to the environment is called for. They might be taken to resemble hierarchies given that there is some level of necessary consent between partners to an alliance on a common course of action under different sets of contingencies. However, they also resemble the market, given that the partners remain independent and are free to pursue their own strategies beyond the alliance.

Even though transaction cost economics is a strong device for analysing governance structures along the continuum of 'make or buy R&D', and the determinants of the vertical integration of firms, both empirical and theoretical analysis of strategic R&D alliances point to several shortcomings of this approach. Perhaps most significantly, empirical research suggests that joint ownership through equity-based arrangements is albeit one specific type of alliance. Even though the definition of a strategic R&D alliance might be considered somewhat vague, it seems that equity-based alliances merely have been the 'tip of the iceberg' in the overall trends. CATI-based research reveals that the share of equity-based alliances has declined sharply since the mid 1980s at the expenses of looser types of non-equity based alliances (Hagedoorn 2002). This trend could also be confirmed in this paper in the case of the ICT sector. Accordingly, it seems that transaction cost is a framework of limited applicability in this context, when the definition of strategic R&D alliances is extend beyond equity-based ones.

Another limitation of transaction cost economics is the focus on governance structures across 'technologically separable stages of production' – i.e. vis-à-vis the position of firms in vertical value chains. In another words, horizontal alliances spanning different value chains are implicitly excluded from the framework. Vertical alliances might be the dominating ones in some industries. Nonetheless, especially in the ICT sector the dynamics of overlapping technology fields, the importance of standardization and the generic nature of technologies implies that firms frequently also have to diversify and become engaged in alliance spanning value chains across technological and industrial boundaries. These types of alliances might be labelled 'horizontal' or 'diagonal' to differentiate them from vertical, 'make or buy R&D' alliances (compare with the discussion in Nooteboom (1999)). In particular, horizontal alliances also differ from hybrid vertical alliances since these typically involve competing firms from competing value chains.

The issue of collaboration and competition as a salient feature of strategic R&D alliances is best addressed in an industrial organizations framework. In this framework collaboration and competition is typically analysed in a two-stage game theoretic set-up in which firms collaborate through an R&D alliance in the first stage, while they compete in the downstream product markets in the second phase (Vonortas 1997). Although this type of sequential two-stage set-up is highly simplified in the light of the dynamics of collaboration and competition in many high-tech industries, it gives a theoretical explanation for why firms might both collaborate and compete during R&D. It also suggests that such strategic R&D alliances have positive welfare effects for society at large, subject to certain assumptions. Consequently, alliance activity amongst competing firms should be supported by policy (as done for example through the EU framework programs). But this policy implication hinges on the degree to which alliances generates knowledge spillovers between participating firms.

The issue of spillovers relates to a further critique of transaction cost economics as an interpreter of strategic R&D alliances. Innovation is an inherently uncertain and wasteful process whereby the investments in R&D seldom generate expected and fully appropriable results (Dosi 1988). Transaction cost minimising by firms in any meaningful sense seems to be a practical impossibility, especially in the R&D-intensive ICT sector. It is thereby fair to conclude that transaction cost economics is a less relevant framework to apply to analysis of alliances in technology fields and industries characterised by rapid technological change, high R&D costs and a fast pace of innovation. More to the point, it seems that a number of alternative theoretical frameworks have more to contribute to an understanding of knowledge spillovers during alliance activity. These frameworks thereby also come closer to interpreting why firms form alliances in technologically complex and highly competitive industries, benefit from this activity, and also generate welfare effects for society at large.

The lion's share of previous CATI based research is rooted in the strategic management literature and the resources based view of the firm. Common to both of these traditions is an emphasis on knowledge complementarities, or knowledge spillovers, as the prime motivation for the formation of alliances. Teece (1986, 1992) offers a conceptually clear extension of transaction cost economics from this viewpoint. Complementary assets are those external technologies and other resources, beyond the control of a firm, which are needed to appropriate innovation. Accessing these complementary assets implies that firms have to develop different degrees of dependency between themselves during collaboration. Complementary assets might be vertically, horizontally or diagonally positioned vis-à-vis a firm. The importance of different types of complementary assets will vary with the stages of technological change and evolution of the industry in question. As a consequence, strategic R&D alliances can also be analysed in a dynamic setting.

The resource-based view of the firm can be viewed as a highly complementary framework, since the focus here is on how firms actually access and make use of these complementary assets. The underlying assumption in this framework is that such assets are firm specific, highly cumulative, tacit and embedded in the organisational setting in which they are used. Alliances are essentially considered as 'learning devices' to facilitate knowledge spillovers and their appropriation. Important issues discussed concern absorptive capabilities, trust and social capital (for a further discussion se Nooteboom (1999)). This discussion thereby also refines the industrial organisation literature by highlighting the complexities involved in appropriating knowledge spillovers. It offers quite different interpretations of the formation of alliances when compared to transaction cost economics – in essence the attention shifts from transaction cost economizing to technology and knowledge transfer under conditions of complexity, high uncertainty and asymmetries between partners. Nonetheless, empirical verification and operationalisation of many important concepts used in the resource-based view of the firms is a problem due to the definitional vagueness of some of this literature (see the discussion in Foss (1997)).

5.2 R&D alliances in the ICT sector

As suggested above, one might define a strategic R&D alliance in a broader or narrower sense. The transaction cost and industrial organisation literature of necessity relies on the narrower definition by focusing on equity-based alliances that are characterised by tight organisational interdependency between the partners. The strategic management literature and the resource-based view of the firm rely on a broader definition. According to this broader definition, an alliance covers most types of inter-firm collaboration that is characterised by reciprocity and bilateralism between the partners, and the institutionalisation of inter-firm R&D collaboration into an alliance through a contractual agreement. Te CATI database has been constructed with an eye to this broader definition of a strategic R&D alliance. Accordingly, the descriptive analysis of alliance activity in the ICT sector in this paper includes inter-firm strategic R&D alliances ranging from equity-based R&D joint ventures and holding firms to non-equity-based joint research pacts and development agreements, R&D contracts, cross-licensing and mutual second-sourcing.

In the empirical section of the paper we defined ICT-related alliances to include the technology fields of microelectronics, software, and telecom. This choice was motivated by the strategic importance of these fields to the development of the ICT sector. An immediate and very clear result is that there has been a steady increase since the mid 1980s of alliances in the ICT sector, followed by an equally clear decline during the late 1990s with the field of telecom as the only exception. While this trend is compatible with previous research on broader trends in alliance activity (see especially Hagedoorn (2002)), it seems that the present and drastic downturn of ICT markets is surprisingly directly reflected also in the intensity of alliance activity. Nonetheless, this trend in the late 1990s might also conceal other types of dynamics beyond the scope of this paper. The ICT sector comprises of a range of different technology fields. Some of these fields might be approaching maturity, whereby competition overshadows collaboration. The decline in the number of newly formed alliances might also reflect consolidation in the industry, whereby the domination of a few larger firms crowds out alliance activity at the fringes of networks – the dominating position of Microsoft in software might be a case in point.

It seems that developments across the different ICT technology fields could be related to underlying technological developments, as illustrated in appendix 2. The analysis of alliances in the context of technological developments would require a more focused and qualitative approach, and the incorporation of technology indicators (e.g. patents) into the analysis. However, within the limits of the database and with resort to previous CATI-based research, some general conclusions can be drawn. Specifically, alliances in the different technology fields appear to be sequentially related, since increased alliance activity in the field of microelectronics – as an important enabling technology – is followed by increased alliance activity in the fields of computers, industrial automation and telecom as the major applications. Moreover, the very rapid increase in software alliances between the late 1980s and mid 1990s (and the rapid decline thereafter) coincides with the development of standardized PC operating systems. Generally speaking, these possible relationships also suggest that alliances have been important means of firms to access external technologies complementary to their core businesses, although previous research on this issue has produced mixed results (compare with Duysters & Hagedoorn (1998); Mowery et al. (1998)).

Beyond these broader trends, there are interesting differences across the ICT technology fields analyzed in greater detail. Significant fields of alliance activity include professional software, chips, private networks and services. A significant share of all alliances is classified to many different technology fields, and these are thus labeled 'multi-technology alliances'. Nonetheless, the field of cellular systems has witnessed a rapid increase in the number of newly formed alliances recently despite the overall decline. This is also the only technology field in which there is clear indication that alliances are larger by the number of partners. Thus, there are reasons to believe that the logic of alliance activity in this field differs from the rest in some important dimensions. One possible explanation might be the paramount importance played by standards and multiple, IPRs to these standards in this field. Previous research points to relationships between the distribution of IPRs, the behavior and position of firms in alliances networks, and markets structures (Bekkers et al. 2002). Previous research also suggests that the analytical attention should shift from dyads of bilateral alliances to alliance groupings, or constellations of multilateral alliances (Duysters et al. (2003). This observation appears to be especially relevant in the field of cellular systems.

When the attention shifts to the actual partners to an alliance, the analysis reveals a high degree of stability over time amongst a few leading firms and countries as the hosts of these firms. Hence, by and large, alliance activity is concentrated to leading firms and countries rather than 'second-tier' firms with weaker in-house capabilities and market positions (compare with Hagedoorn & Schakenraad (1992)). The dominance of large US conglomerates is quite clear across all three ICT technology fields analyzed in the paper, and especially so in software due to the domination of Microsoft. This dominance of the US is even more striking according to the ranking lists of the position of different countries as the hosts of partner firms to alliances. Accordingly, it seems that the US also hosts a range of other smaller firms beyond the industry leaders, which a frequent partners to alliances. This dominance of the US is also on the increase across the board. Beyond this, especially Japanese and European firms score high by the number of alliances.

However, on closer inspection there are interesting shifts and differences across technology fields when moving down the lists. A general observation is that the fields of microelectronics and software are to a much greater extent dominated by US and Japanese firms when compared to the field of telecom, in which European firms have a more significant position. In telecom the more significant position of firms such as Ericsson, Siemens and Nokia probably relates to the GSM breakthrough. Nonetheless, large and diversifies non-European firms are also active. Interestingly, this field is also characterized by the entry into alliances of China and Taiwan amongst the top ranking countries. A noteworthy observation is the rise of Nokia and Finland in software and telecom. South Korea is another new 'outsider' alongside US, Japanese of European firms, especially in the field of microelectronics.

The data in the CATI database also allows for a typologisation of alliances by the organizational interdependency between partners to an alliance. We argued that this typologisation ties directly to the theoretical frameworks reviewed in this paper. The point made above was that the rapidly declining share of equity-based alliances highlights limitations of applying transaction cost economics in this context. On closer inspection this same trend is evident across all three ICT technology fields analyzed in this paper. In the 1990s the share of equity-based alliances has reduced to 12 percent, while over 80 percent of all alliances across the technology fields are non-equity based joint research pacts (JRPs), joint development agreements (JDAs) or R&D contracts (RDCs). The share of cross-licensing, standardization and mutual second sourcing agreements is relatively small.

A noteworthy result is nonetheless that the field of telecom has witnessed a relatively larger share of equity-based R&D joint ventures when compared to microelectronics and software – thus firms in telecom alliances are more often more closely tied together in an alliance. We suggested that this might relate to the paramount importance of standards in this field, which might call for tighter governance structures to facilitate close collaboration and interactive learning in technologically complex technologies. A concrete example could be the GSM standard, which led to the formation of several competing alliances between firms, some of which were R&D joint ventures (Bekkers et al. 2002; Palmberg & Martikainen 2003). More generally, this result suggests that the nature of technological change has implications for the ways in which firms organize knowledge exchange during collaboration.

5.3 Some future research directions

Despite the recent drastic decline in the number of newly formed R&D alliances in most technology fields of the ICT sector, there is consensus in the literature that alliance capitalism is here to stay (Caloghirou et al. 2003; Dunning & Boyd 2003). According to Caloghirou et al. (2003) the main reasons for why this will be so is that the complexity and speed of technological change is continuously picking up, whereby there is a widening diversity of competence that need to come together to complete a R&D task in industry. Above all, strategic R&D alliances are a means of firms to bet on different technological options and thus handle the uncertainties related to these developments. Thus, there is also a need for future research on strategic R&D alliances, especially in the high-technology sectors. We would like to suggest a few research directions here, some of which would require complementary data to that contained in the CATI database.

A first research direction to take would be to develop measures for distinguishing between alliances based on their economic significance, stability over time or success in some other dimensions. The industrial organization literature indicates that alliance activity might have positive welfare effects on society at large, by correcting market failures in R&D. However, these effects will obviously be unevenly distributed amongst firms in alliances depending on initial and contextual conditions, on the specific governance structures and contractual agreements of alliances. From a normative viewpoint, it would likewise be important to identify factors contributing to the differing success of strategic R&D alliances. The extent of spillovers between the partners in an alliance has been singled out as especially important. Even though spillovers are notoriously difficult to identify, let alone measure, there is clearly a need to elaborate further on this proposition through in-depth research.

From the scantly available empirical research we learn that the relative similarity of firms in terms of their patenting profiles and their basic strategic orientations vis-á-vis the balance between in-house R&D and networking, are important in this context (see e.g. Lane & Lubatkin (1998); Vanharvebeke et al. (2001), and Duysters et al. (2003)). An especially interesting issue is how competitive constellations in the downstream product markets affect alliance activity and the extent of spillovers further upstream throughout the alliance networks of firms – hence far the literature remains highly theoretical on this particular issue (Kogut (1988) and Vonortas (2000) are two exceptions). It seems that alliance capitalism essentially is a 'strategic game' amongst a few leading firms from the world's most developed countries. Although firms declare that alliances are designed for the mutual gain of all partners the underlying power structures, and other asymmetries between partners, often come to dominate with adverse consequences.

Even though CATI is the largest database available on strategic R&D alliances, it nonetheless seems to be biased in favour of these leading firms from the highly developed Anglo-Saxian countries. Based on the descriptive empirical analysis of the core ICT technology fields the impression is that Finland has entered alliance capitalism mainly through Nokia as the leading firm in the mobile telecom industry. However, beyond Nokia it is clear that the database is patchy since it does not include a range of other important Finnish fims. Finland is a small open economy that is pursuing a knowledge-based strategy. Accordingly, it would be highly valuable to complement the CATI database through a better coverage of these other large firms in order to gain a better understanding of the internationalisation of Finnish firms through strategic alliances, on the types of partners and technology fields that have been involved, and on the position that these firms have in alliance networks and the global division of labour in R&D.

Beyond complementing the database from a Finnish viewpoint, another research direction is to investigate in more detail the relationships between technological change and patterns of alliances across technology fields. In this paper we suggest that the peaks and bottoms in the number of newly formed alliances have coincided with major technological developments in the ICT sector. Alliance capitalism in the 1980s appears to have been largely driven by the introduction of commercial microprocessors and DSPs, as well as by the GSM. The 1990s appears to have been characterised by the development of standardized PC operating systems, thereby strengthened the position of US firms (especially Microsoft). Apart from investigating these relationships in greater detail, it would be interesting to map recent developments related to the IP-protocol onto patterns of alliances. These recent developments are especially profound with respect to established value chains and business models, and should thus also affect the alliance activities of firms (Li & Whalley (2003); Martikainen (2002)).

The importance of standardisation in the ICT sector also raises some important questions. According to Shapiro (2003), tensions between firms related to agreeing on overlapping patents are especially common in the case of standardization, since firms thereby also bring new technologies to the market. Strategic R&D alliances are one means to settle such tensions between firms. Nonetheless, the relationships between standardisation, patenting and R&D alliances have received relatively little research. In particular, it is unclear how the distribution of patents – or IPRs more generally – relates to the structure and power constellations of alliance networks. The historic case of GSM points towards an association between extensive patent portfolios of firms and a significant position in alliance networks (Bekkers et al. 2002). Consequently, it seems that a strong position with respect to IPRs over a new technology also strengthens the position of firms in alliance networks, for example in terms of their bargaining power. Further research along these lines is important due to the overall growing importance of IPR issues in the ICT sector (BRIE-IGCC E-economy project 2001.).

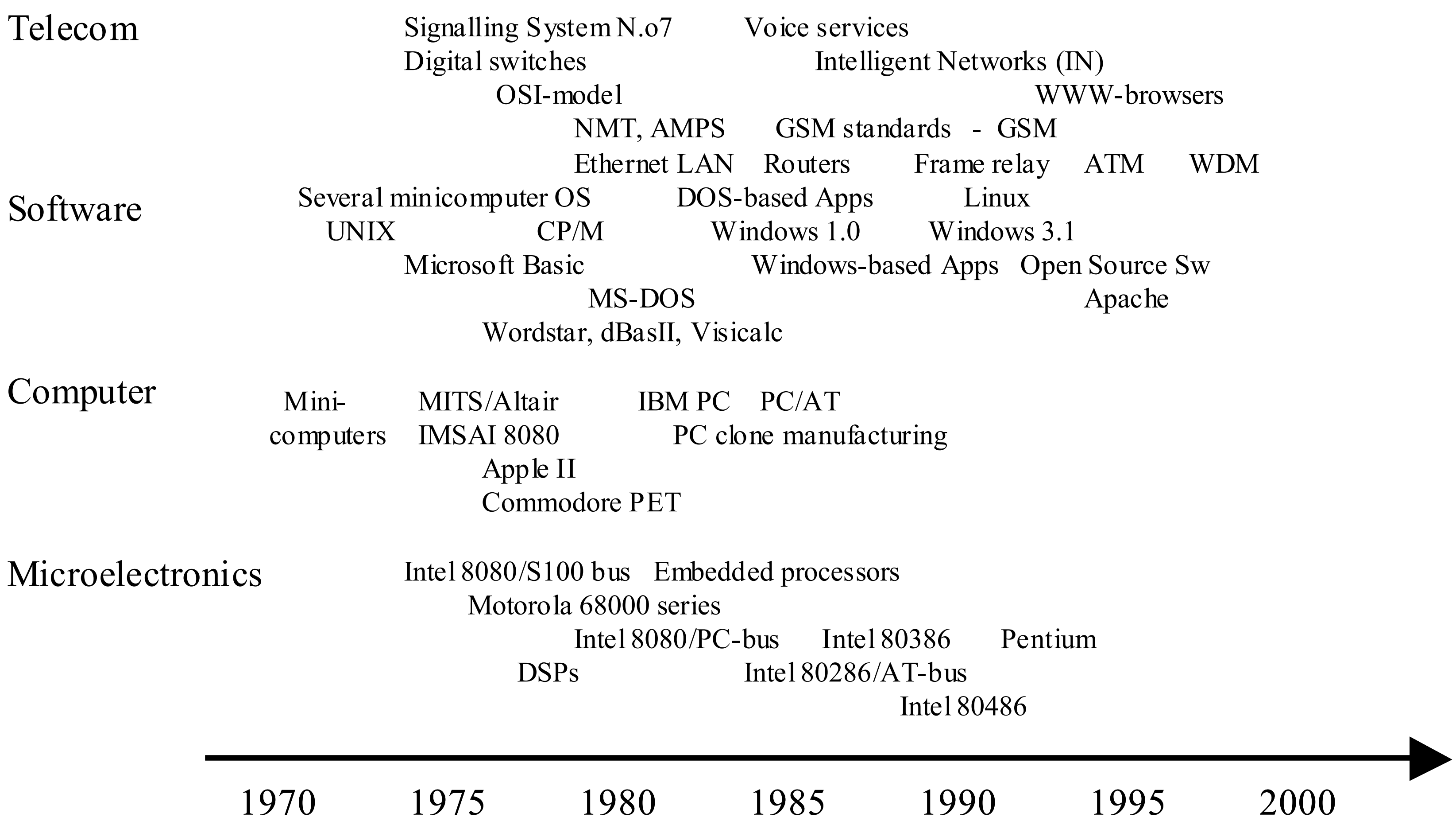
Finally, there is some indication that alliances, especially in the field of cellular telephony, are increasing in size over time. There are also concrete examples of the formation of such large alliances around specific technologies, such as the Nokia-led Symbian alliance that includes multiple significant firms in the industry with a focus on developing a software platform for next generation mobile phones. This raises the broader issue of whether competition between firms is being replaced by competition between constellations of alliances, as argued by Duysters et al. (2003). Further research is needed on how alliance networking relate to the other strategies and intentions of firms, based on case studies. Furthermore, there is a range of policy issues to be addressed with respect to how national advantages can be created in alliance capitalism, if at all.

Appendix 1 – Aggregation of CATI technology fields*

* Fields labelled 'multi-technology' comprise of combinations of technology fields within respectively microelectronics, software and telecom.

ICT sector	ICT technology fields in CATI	Technical content and definitions	ICT technology fields in this paper
Micro-electronics	A. Processors, Accelerator Chips	Computer processors and added ICs	**MA. Processors**
	B. RISC Processors	Reduced Instruction Set Computer processor	
	C. Memory Chips, Peripheral Chips	Memory chips and peripheral driver ICs	**MB. Chips**
	D. ASICs	Application Specific Integrated Circuits	
	E. Expansion and other Chip Boards	Other including audiovisual, TV, car	
	F. Transistors etc.	Generic components	**MC. Other generic components**
Software	A. Standard Software	Operating systems and office software	**SA. Standard software**
	B. Dedicated Software Packages	Industrial software including database, CAD and telecom	**SB. Professional software**
	C. Custom Supply Dedicated Software	System software and software components	
	D. CASE	Computer Aided Software engineering and other tools	**SC. Other miscallenous software**
	E. Edutainment, Games	Education and entertainment	
	F. Internet Software	Internet software	
Telecom	A. Public Exchanges	Switching systems for fixed networks	**TA. Public networks**
	B. P(A)BX, LAN, VAN, WAN, ISDN, HIS	PBX, local area, data and value added networks covering speech and data	**TB. Private networks and services**
	C. Cellular Telephony	Mobile phones, base stations, switching system and mgmt. tools for mobile networks	**TC. Cellular systems**
	D. Equipment	Transmission and miscellaneous equipment	**TD. Other systems**
	E. Telematics	Should be telefax, videotex and email systems	
	F. Miscallaneous		
	G. Internet Boxes, Net PC	Internet terminals	

Appendix 2 – Major technological developments in the ICT sector 1975-2000
(Source: Langlois & Robertson 1992; OECD 2000)



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