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International R&D Alliances by Firms: Origins and Development

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Abstract
There has been a dramatic increase in all forms of international cooperation in science, technology and innovation over last three decades. This chapter focuses on a specific subset of such cooperative agreements: those that primarily (but not exclusively) involve firms that seek some commercial benefit from the outputs of inter-firm collaboration, known as strategic technology partnering (STP). Special attention is given to clearly define the unique nature of these collaborative agreements, as well as the reasons and theories behind their growth. We focus on their international dimension, identifying *international* STP trends, and how the cross-border aspect of these alliances impinges on their formation and success. Finally, managerial challenges and policy implications related to STP are also discussed.

Keywords
R&D alliances, strategic technology partnering, technological partnerships, R&D internationalization, technology policy, multinational corporations

JEL Classifications
O32, L24

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1 Introduction

One of the hallmarks of globalization has been the growing interdependence of firms across borders, and the greater variety of organizational modes deployed by companies. Globalization has not always been a force for positive outcomes: Firms have greater opportunities, but these are matched by commensurate challenges. The liberalization of markets, the decline of barriers to trade and investment and the greater cross-border enforceability of contracts has expanded the de facto markets available to firms, while also increasing cross-border competition. New systemic technologies and the growing need for firms to have a greater breadth and depth in a variety of scientific and technological areas have also changed the competitive landscape. The dynamism and complexity of the marketplace and the intertwining of such technological and economic forces has meant that it is difficult for firms to effectively compete when relying entirely on their own resources.

Globalization and technology are deeply interconnected and concatenated at multiple levels, and the growing international, cross-border aspect of collaboration is regarded as one of the primary categories of the well-known tripartite taxonomy proposed by Archibugi and Michie (1995). The greater interaction between users and producers of scientific knowledge has naturally led to greater collaboration and interaction between a variety of actors, and it should be stressed that this collaboration is not limited to commercial, for-profit economic actors. There is a considerable degree of exploitation and generation of knowledge that is facilitated through informal and formal collaboration, inter alia, through migration, expatriation, student exchanges, scientific cooperation, conferences, and so on (Archibugi and Iammarino 2002). In addition, the large role of non-firms (which we take to mean actors that do not have a primary economic motivation, such as universities, colleges, public institutes, regulatory authorities, and so on) should not be underestimated (Narula 2003). However, this chapter intentionally focuses on collaboration between entities that have at their heart a commercial motivation behind their activities.

It is not an accident, then, that the past few decades have seen a rapid growth of collaborative agreements between firms (Narula, 2003). This trend is particularly evident in those industries where consumption patterns are more homogeneous across countries, and which show a high level of capital intensity as well as knowledge intensity in terms of investment in innovation and technology (Narula and Duysters, 2003).

Collaboration in innovation does not necessarily mean that innovation is the primary intention, but may be a consequence of exploitation. Indeed, some have described the current era as being the "age of alliance capitalism" where flexible economic arrangements are finding increasing favor (Dunning, 1995, 1997). It should be noted that growing collaboration has not led to the death of the 'traditional' firm. Instead, cooperative arrangements have, in many cases proven to be supplementary to hierarchical, fully internalized activities within the boundaries of a vertically or horizontally integrated firm (Dicken 2011). It is not entirely new either – economic actors have relied upon cooperation to gain competitive advantage since time immemorial[1].

Nonetheless, it is now an especially large and pervasive phenomenon, and the increased use of collaborative agreements has been observed by all firms independent of their size and country of origin. Firms have always needed external partners (suppliers, competitors, customers, universities, technological research centres or institutes) to collaborate with on different, specific activities along their value chain (Narula and Duysters, 2003), but the extent to which firms in the 21st century systematically exploit cooperative networks and agreements is quite breathtaking.

In this chapter we focus on R&D alliances, or strategic technology partnering (STP) (these terms are used as synonyms here). We intend to highlight two specific characteristics of the current growth of cooperative activity that are novel to the current era. First that the last three decades have seen cooperative agreements increasingly being used for high-value and knowledge-based activities, such as those related to research and development (R&D). It turns out that the growing complexity and multidisciplinary nature of the innovation process has implied a greater need for firms to be flexible and responsive to external partners in order to access complementary resources, to take advantage of more business opportunities, achieve lower costs, or reduce time-to-market (Duysters and de Man, 2003; Hagedoorn, 1993; Martínez-Noya, García-Canal and Guillén, 2012). In effect, technological change and global competition have forced firms to search for external sources of knowledge through a wide diversity of alliances (Hagedoorn and Osborn, 2002).

Second, we pay specific attention to *international* alliances, which are agreements that are international in their span and partner selection. Theoretical work over much of the 20th century has argued that, due to the strategic and usually tacit nature of R&D, firms have tended to centralize this activity in the home country and to internalize it (i.e. maintain in-house) to maintain control over the assets. Firms preferred, wherever possible, to establish wholly owned subsidiaries, and where this was not possible for whatever reason, to maintain a controlling stake

[1] Intricate linkages between economic entities that create informal and formal networks to undertake value added activity dates back to before the 17th century, where production of goods was undertaken by 'putting out'. Rapid Japanese industrial growth over the last century has been partly attributed to the cooperation between interlinked firms with limited equity cross-holdings within industrial groups.

in its affiliate. This was considered to be particularly so when engaging in foreign markets, so as to protect their technology and avoid appropriability hazards (Kogut 1988; Oxley 1997). However, over the past few decades this preference for full internalization has changed, even for R&D intensive firms (Martínez-Noya and García-Canal, 2011).

The great paradox of globalization is evident in the analysis of R&D alliances: countries, governments and nation-states matter more, even as economic activity is increasingly cross-border, and national borders matter less (Narula 2003). There remains heterogeneity of country-specific resources, and these are geographically bound. The external resources needed by a firm may not be available within its home country, and these cross-country differences in resource endowment may drive the firm to seek such resources internationally (offshore), searching for location-specific advantages (Dunning, 1998). Nowadays, knowledge-intensive firms from both advanced and developing countries are globally dispersing and disintegrating their value chains to control costs and leverage their capabilities (Mudambi, 2008). Through STP firms have found a way not only to be more efficient or flexible, but also to benefit from the distinctive capabilities of specialized partners located worldwide (Chen, 2004; Graf and Mudambi, 2005) even from emerging countries (UNCTAD, 2005).

2 Defining strategic technology partnering (STP)

This chapter is focused on (international) strategic technology partnering (STP), which represents a particular subset of cooperative agreements. STP refers to inter-firm cooperative agreements where R&D is a significant part of the collaborative effort, and which are intended to affect the long-term product-market positioning of at least one partner (Hagedoorn 1993). Compared to quasi-external, vertical solutions such as outsourcing and customer-supplier networks (which tend to involve lower levels of joint activity) STPs are usually horizontal agreements which tend to reflect a more complex strategic intent, and require closer collaboration (Narula and Hagedoorn 1999, Narula 2001).[2] The word ‘strategic’ in STP suggests that such agreements are aimed at the longer-term objective of enhancing the value of the firm’s assets.

[2] *Horizontal collaborative agreements* are those among firms operating in the same industry, engaged in roughly the same kinds and types of value adding activity. The opportunities for economies of scale and scope are here maximized, but also provide the possibilities for conflict and leakage of intellectual property from one partner to the other. *Vertical collaborations* occur among firms operating in related industries along the same value chain, where one partner produces inputs for the other. These agreements tend to be less problematic, as *a priori* the partners possess complementary but not competing capabilities and opportunities. Their primary (but not the only) motivation is towards reducing costs.

This definition is important to note because there are a variety of cooperative agreements that do not have a primary strategic intent, but are primarily cost-economizing: for instance those associated with global value chains and production networks, where the primary objective is to reduce costs along a vertical chain. A strong strategic motive implies that the firm is often willing to forego (some degree of) cost-savings in order to strengthen its portfolio of assets or its competitive position, or at least to defend its current position. Needless to say, most agreements have elements of both, but horizontal agreements tend to have a greater strategic aspect.

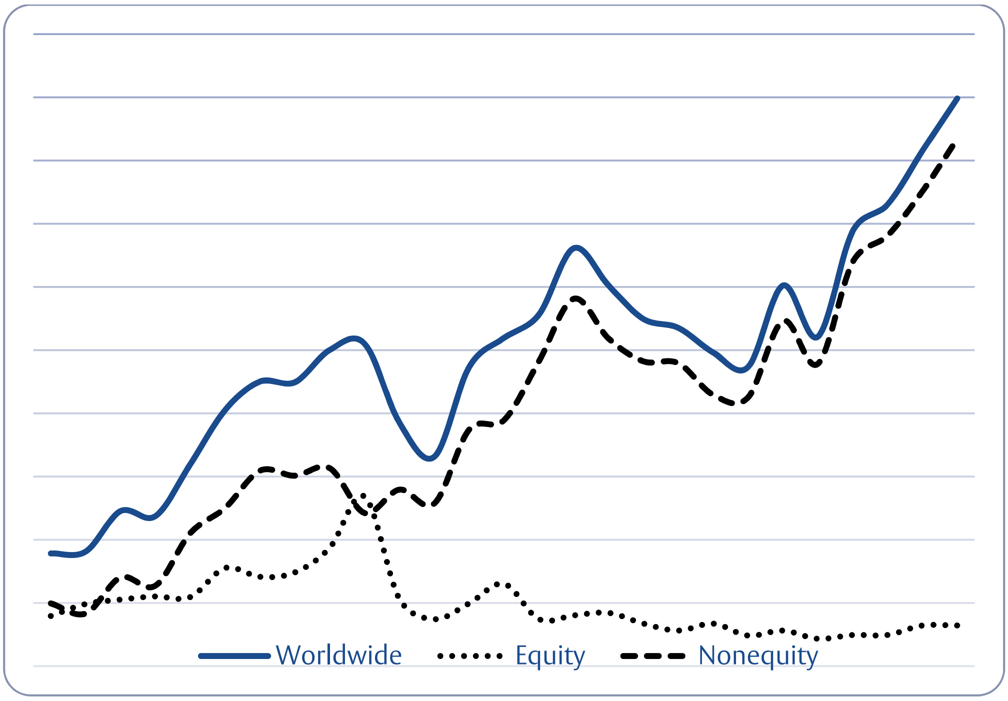
STP differs from other kinds of alliances in several ways.

1) STP is often designed to undertake specific tasks and are generally terminated at the completion of these tasks, and are by definition short- (and often fixed-) term in nature, unlike non-R&D alliances and networks which may have a long-term and formal aspect which link aspects of their businesses (Porter and Fuller 1986).

2) STP also differs from other strategic alliances in that while firms engaged in asset-exploiting activities such as production or sales have a broader choice of options, that include wholly owned subsidiaries and arms-length technology acquisition, some of these options are simply not available to firms that are seeking to undertake R&D. On the one hand, R&D is partly tacit, surrounded by high levels of uncertainty and has a long-term horizon. As such, the value of the research cannot be estimated *ex-ante*. On the other hand, arms-length transactions are simply not as effective, particularly in technology-intensive sectors or new, ‘emerging’ sectors, even if markets for these technologies were to exist. The further away these technologies are from commercialization, the less likely that technology can be obtained through market mechanisms. Besides, the partly public good nature of these activities prevents prospective selling firms from making technologies available for evaluation, and without doing so the prospective buyer is unable to determine its worth. Thus full internalization may simply not be a choice available to the MNE, and the use of mergers or acquisitions (M&As) or greenfield investments may not be advisable either. First, because it is known that the use of M&As is not a viable option where the technology being sought is a small part of the total value of the firm (Kogut 1988). Second, due to the high dynamism of the technological market, a greenfield investment may not be viable either, because the time and costs of building new competencies from scratch may be prohibitive. In relation to this, it should be noted that in some instances alliances are used as a precursor to M&As (Hagedoorn and Sadowski 1999). Therefore, it is no surprise that STP has grown fastest in high technology sectors where market options are less well-developed. In general

though, partnering activity has steadily declined as a percentage of all agreements in all sectors (Hagedoorn 2002). (Figure 1).

Figure 1: Worldwide equity and non-equity technology alliances (1980-2006)



SOURCE: MERIT-CATI database, as published in *Science and Engineering Indicators 2010, National Science Foundation*

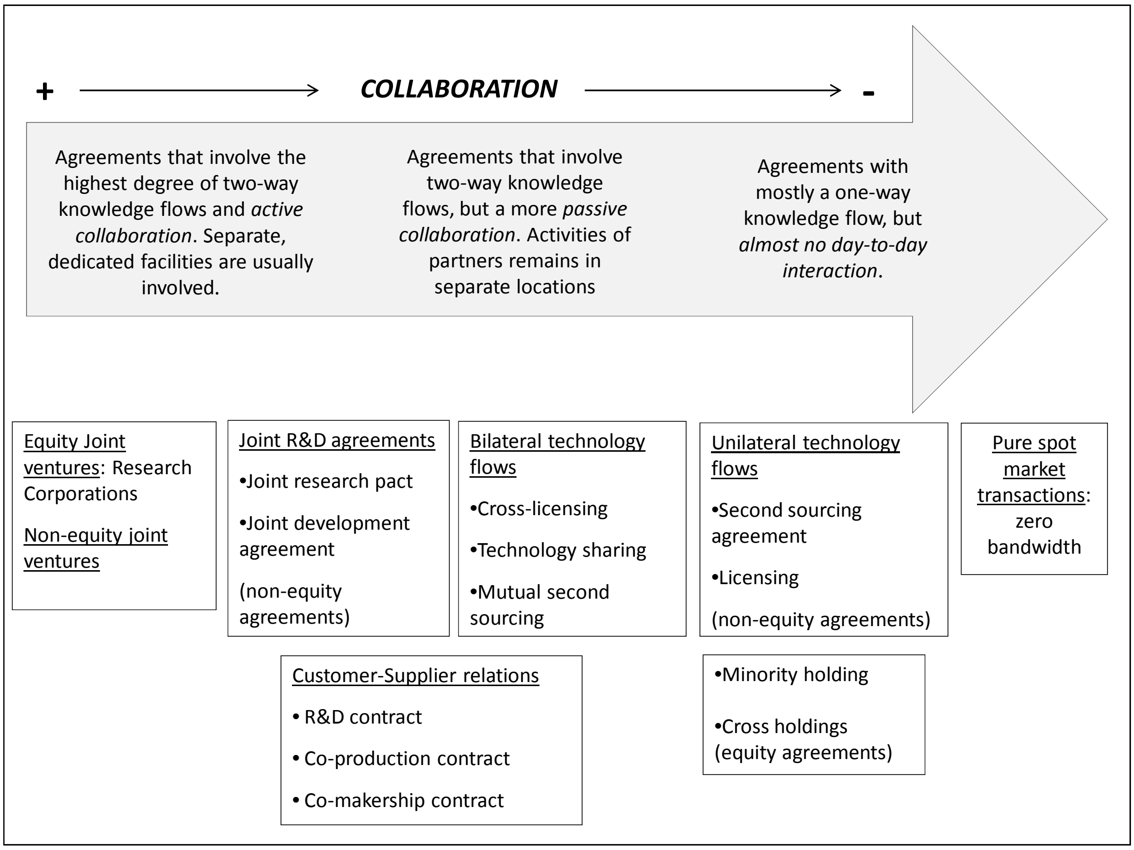
2.1 Databases on STP

Although often complemented with additional data sources stemming from survey data or news retrieval searches, studies on research and technology alliances tend to utilize large alliance databases such as Securities Data Company (SDC), Bioscan, MERIT-CATI, Recombinant Capital (RECAP), or CORE. Three are multisector databases (SDC, MERIT-CATI, and CORE) and two databases are specific to the biotechnology sector (RECAP and Bioscan). Each of these databases has its unique advantages and disadvantages: see Schilling (2009) for an extensive review on their differences. Therefore it is important to know them so as to use the most appropriate one depending on the type of research to be undertaken. Given that SDC and MERIT-CATI databases have been found to be the most appropriate for large-scale analyses on STP, their main features are described. On the one hand, SDC is a division of Thomson Financial and is the most commonly used database covering the widest range of sectors and details over 138,000 worldwide joint ventures and strategic alliances. Specifically, SDC tracks cooperative agreements by two or more separate entities that may result in the formation of a third entity, either as a start-up or through the merger of assets, or acquisition of stakes; as well as agreements involving licensing, manufacturing, research and development, mining & exploration, supply services (Thomson Reuters, 2014). Thus, although R&D alliances are just a subset of the data available through the mergers and acquisitions section of the database, the main advantage of SDC is its extensive searchability. It offers over 200 data search elements including the name, SIC code, and nationality of participants, the terms of the deal, and deal synopsis for each alliance agreement. On the other hand, the MERIT-CATI database, administered at Maastricht University in the Netherlands, is focused exclusively on STP, which includes any alliance that entails the transfer of technology or the undertaking of joint research, such as joint research pacts, joint development agreements, R&D contracts, (mutual) second sourcing agreements, and joint ventures with technology sharing or an R&D program. The key strength of the MERIT-CATI database is that it tracks data since 1960 which makes it very valuable for looking at long-range STP historical trends. The disadvantages are however that the availability of this dataset is restricted (2006 was the last year for which data was available published in Science and Engineering Indicators 2010, National Science Foundation, at the time of this chapter), and that it only includes agreements that have at least two industrial partners, thus alliances involving only government labs or universities, or one industrial partner with a university or lab, are not included. Also excluded is subsidized R&D cooperation such as agreements established under the auspices of the EU framework programs. Overall, it should be noted that independently of the dataset chosen, Schilling (2009) found that even though the databases only capture a sample of alliance activity, many all these databases exhibit strong symmetries in patterns of sectoral composition, alliance activity over time, and geographic participation, thus yielding reliable results.

2.2 The growing variety of organizational modes in R&D alliances

There are a wide variety of STP agreements. Figure 2 lists the most common types. Strictly speaking, licensing agreements do not often involve active collaboration, and knowledge flows are largely one-way (with the exception of sporadic flows due for instance to legal clauses that require the licensee to feedback to the licensor improvements and innovations they may have made to the licensed technology). Licensing agreements are therefore passive conduits for knowledge flows, and do not normally qualify as alliances *by themselves*. Similarly, two-way licensing agreement, mutual second sourcing and cross-licensing, involve knowledge flows, but have a minimal degree of collaboration. They are also – by definition – utilized where knowledge has been codified. Nonetheless, they are likely to have a strategic element to them, because they may be a precursor for more complex and intense collaboration, and may also be utilized in parallel with more interactive collaboration. Indeed, there are few instances where more complex joint R&D alliances do not also involve an exchange of technology licenses, and other lesser forms of collaboration.

Figure 2. Organizational modes of STP agreements and extent of inter-firm collaboration

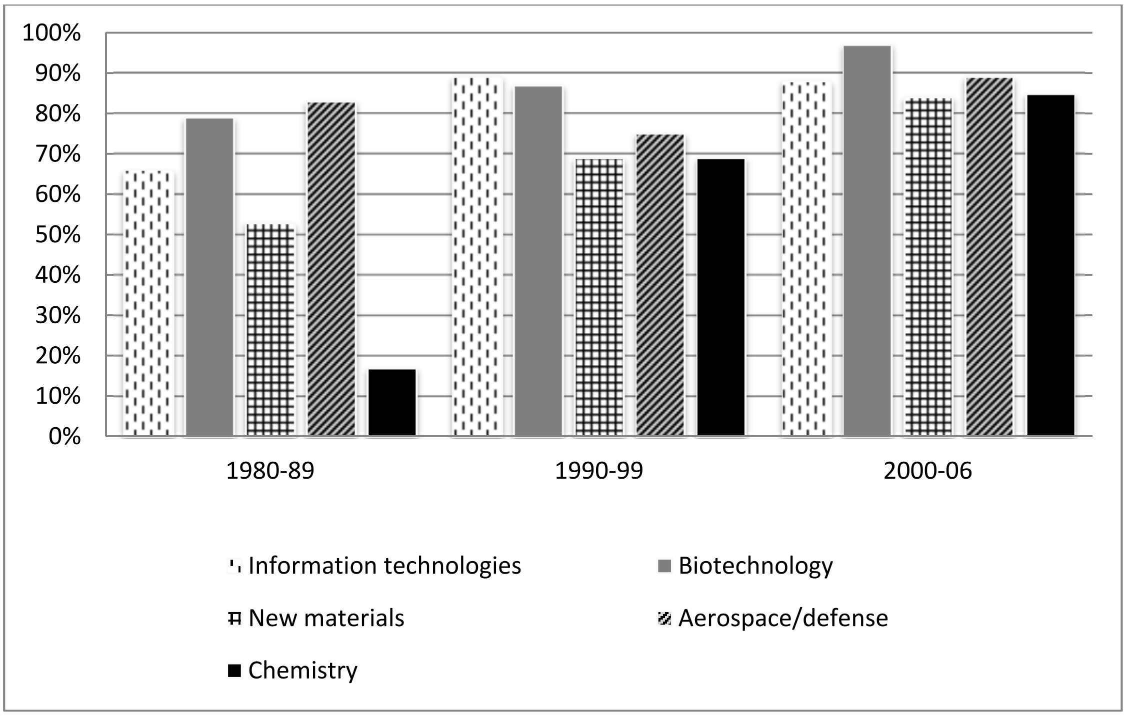


Source: Authors' elaboration

Thus, the extent and form of interaction between learning activities depend upon the organizational form of cooperation, and this varies considerably by industry and by the relative importance of specific technologies to the firm's portfolio of competencies. On the one hand, non-equity forms of agreements tend to be more efficient for undertaking activities in more research-intensive industries, and where technological change is rapid since they promote negotiation and can lead to more intensive cooperation than equity forms. However, where firms seek to learn and transfer tacit knowledge back to the parent firm, such as market-specific knowledge when entering a new market, or are engaged in production as well as research, equity forms of agreement may be more appropriate. Equity agreements are preferred in relatively mature sectors, while non-equity agreements are utilized in high-tech sectors (Hagedoorn and

Narula 1996). Figure 3 shows the differences in the preference for non-equity agreements by major sectors. By and large, there has been a growing preference of non-equity agreements across all sectors, and this reflects the declining coordination costs of STP, as well as their ability to monitor and enforce their intellectual property rights within the growing framework of international and national regulations governing intellectual property rights.

Figure 3. Percentage of non-equity agreements in industrial technology alliances by sectors (1980-2006).



SOURCE: MERIT-CATI database, as published in *Science and Engineering Indicators 2010, National Science Foundation*

On the one other hand, the preference for alliances relative to other modes is also determined by the relative importance of specific technologies to their portfolio of competencies. The strategic importance of these technologies determines to what extent firms will use alliances or outsourcing in their development. This, in turn, is determined by the extent to which the technology is tacit, the extent to which collaboration is required to utilize it, and to what extent the partner's activities need to be monitored (Narula 2001). In addition, the maturity of the technology, and its characteristics, determines the extent to which the innovation process can be internalized (Teece 1986, 1996). Furthermore, not all new technological developments are equally important to a firm's technological portfolio, and this influences the choice of organizational mode.

The facilitating role of globalization has expanded firms' use of external resources to reduce, *inter alia*, innovation time spans, costs and risks associated with innovation, as well as provide firms with greater flexibility in their operations (Hagedoorn 1993). The increased knowledge content of products in general, the cross-fertilization between previously distinct technological areas, coupled with the multiple technological competencies that modern products, services and processes require of firms put growing pressure on their in-house resources, which are limited. So firms must collaborate it they are to overcome this resource bottleneck. Falling coordination, monitoring and enforcement costs have made it easier for firms of all sizes to monitor, identify and establish collaborative ventures than previously had been the case (Narula 1999; Rangan, 2000). In other words, hierarchical control and full internalization is no longer always a first-best option to MNCs, especially where innovatory activities are concerned.

Internalizing activities under conditions of rapid technological change impose inflexibility precisely when flexibility is most needed (Poppo and Zenger, 1998). In fact, the literature analyzing strategic technology partnering has found that whenever firms need quick responses to changes in technological leadership, non-equity agreements are preferred to joint ventures because they provide firms with greater strategic flexibility (Osborn and Baughn, 1990). Due to the fact that investments in technology are often quite specialized, rapid technological change may increase the likelihood of technological investments in knowledge and routines being rendered obsolete (Balakrishnan and Wernerfelt, 1986). For this reason, previous research has shown that greater use of non-equity agreements may deliver more flexibility, which may help firms to respond quickly to unanticipated threats and market opportunities (Hitt et al., 1998).

As figure 3 shows, the fraction of non-equity STPs has been growing over the last 25 years. One can interpret this as evidence of the fact that low-commitment intensive agreements are more effective as a mechanism to gain timely and extensive access to rapidly evolving technology across borders. From this perspective, STP may represent a "first-best" option to MNEs (Narula 2003), especially where innovatory activities are concerned. In other words, firms do not necessarily resort to these strategies because they cannot have access to more effective and more profitable channels of technology transfer (as uncertainty is too high or institutional barriers constrain "internal" strategies); on the contrary, STPs, especially non-equity agreements, can be preferred as a tool that is both more flexible and more apt for knowledge development and learning.

2.3 Does STP substitute for in-house R&D?

Considerable research has sought to understand how much a firm can substitute STP for in-house R&D. The attempt to understand the reasons behind a firm's choice between non-internal and internal technological development is not new. The work of Teece (1986) presents a pioneering analysis of this issue, which builds on Abernathy and Utterback (1978), Dosi (1982) among others, and further developed by Pisano (1990), Arora and Gambardella (1990), Henderson and Clark (1990), Granstrand et al (1997), Buckley and Chapman (1998), Nagarajan and Mitchell (1998), Veugelers and Cassiman (1998), Croisier (1998), Lowe and Taylor (1998), Tidd and Trehwalla (1997), Gambardella and Torrisi (1998), Nooteboom (1999), Narula (2001) and Brusoni et al (2001).

Cooperative agreements act as complements rather than as substitutes for traditional hierarchical modes. This is because the excessive use of non-internal R&D entails considerable risks and costs. As a general rule, firms find it costly and difficult to access competencies from other firms or organizations in technological fields which are unrelated to their own capabilities, and with which they have little initial familiarity. The point is that the internalization advantages of undertaking a variety of activities in-house derives (*inter alia*) from the technological coherence of these activities (Teece et al., 1994). Where such technological coherence does not exist, non-internal activities become feasible options. However, this feasibility is a function of the firm's 'absorptive capacity'. When the firm acquires knowledge from its external environment or where one knowledge-creating part of the firm interacts with another, the recipient needs to have some innovative potential of its own to be able to learn and effectively adapt the technologies to which it may wish to have access (Cohen and Levinthal, 1989). Thus, STP tends to develop in areas in which partner companies share some complementary capabilities, and these alliances create a greater degree of interaction between the partners' respective paths of learning and innovation (Mowery et al 1998, Cantwell and Colombo, 2000, Santangelo 2000).

STP is not an alternative to in-house R&D, but complementary to it. STP, and other collaboration modes do not replace the need for firms to undertake internal R&D activities, but it enhances it. Indeed, Veugelers (1997) demonstrates that there is a positive relationship between external technology sourcing and internal R&D. Firms must know considerably more about what they need (and do not have) to both monitor their partners, and also to be able to efficiently perform the role of systems integrator (Brusoni et al., 2001). Such a threshold level of expertise provides them with the absorptive capacity to benefit from external sources of knowledge (Cohen and Levinthal, 1990). STP tends to be highly correlated with large firms with ample resources in technology-intensive sectors, and is most frequently the means firms use to keep up with the technological frontier. By associating complementary resources and competencies STP makes it possible for firms to explore and exploit new technological opportunities and expand the boundaries of their knowledge base.

3 Theoretical perspectives to explain growth of STP

The growth of STP has been explained taking either a economizing perspective through the lens of transaction cost theory, or a more strategic one through the lens of a number of different theoretical perspectives, such as the resource-based theory of the firm (Barney, 1991; Das and Teng, 2000; Wenerfelt, 1984), the dynamic capabilities approach (Teece, Pisano and Shuen, 1997; Zollo and Winter, 2002), the knowledge-based view and organizational learning theories (Kogut and Zader, 1993), as well as social network theory (Gulati, 1995; Powell and Grodal, 2003). Overall, the underlying the difference between the economizing and the more strategic perspectives is a fundamentally different view of the way firms make decisions. Transaction cost theory assumes that firms' internalization decisions are driven by their desire to seek protection from opportunism, while the strategic theories highlight the fact that firms are boundedly rational and undertake decisions based on the need to enhance their organizational and technological capabilities; i.e. because they need to enhance the value of the firm.

The transaction costs or internalization perspective —which derives from Williamson (e.g., 1975) and Coase (1937)—explains the behavior and organizational mode and the mode of entry of firms based on their need to *minimize net transaction costs* faced by the firm. This body of literature has been expanded by others including Buckley and Casson (1976), Hennart (1993) and Rugman (1980). From this economic perspective, one of the fundamental reasons for the growth in STP (and in alliances in general), is the reduction of transaction costs faced by firms as a result of globalization of markets. On the one hand, recent improvements of information and communication technologies (ICTs) have reduced the costs of communicating and coordinating with external partners, which have also facilitated management of international arrangements. On the other hand, economic liberalization of markets has also led to a harmonization of regulations and barriers across countries, which has reduced the costs of enforcing and monitoring international alliances and contracts. In this sense, the establishment of supra-national regional and inter-regional agreements such as the EU in Europe, NAFTA in North America have all helped to further lower transaction costs within firms located in those regions.

However, as we have emphasized throughout this chapter, the reduction of transaction costs is only a partial explanation for the growing use of STP as a viable option to in-house R&D. As argued by Narula and Dunning (1998) four primary characteristics differentiate collaborative activity in the era of alliance capitalism from those in earlier periods. They observed that in this new era: (i) alliances are not primarily made to overcome market failure; (ii) alliances are increasingly undertaken to achieve not only vertical integration, but also horizontal integration; (iii) the use of alliances has been expanded worldwide and became typical of most advanced industrialized economies; and finally (iv) while alliances were previously made primarily to enhance or achieve market entry or presence (i.e. asset-exploitation motives), in recent decades they are increasingly being made to protect or enhance their technological assets (i.e. asset-creation or acquisition motives). It is for these distinctive characteristics that a growing number of recent studies assert that the firms' decisions to internalize are subject not only to a cost minimization strategy, but also determined by value-enhancing considerations.

Indeed, there are seven factors of a more strategic nature that explain much of the growth of STP in the past few decades.

1) The emergence of new technological sectors (such as biotechnology) and the growing technological convergence between sectors (such as computers and automobiles, or new materials with transportation) have played an important role. The cross-fertilization of technological areas has meant that firms need to have an increasing range of competencies (Granstrand et al 1997), which encourages the use of STP to seek complementary assets rapidly.

2) Firms do not always have recourse to patenting as a means to protect their intellectual property, and must rely on secrecy or co-invention instead (Levin et al 1987, Arundel and Kabla 1998).

3) By co-invention, alliances allow firms to monitor competitors. In certain cases, firms may also engage in STP in order to co-opt the competition (Narula and Dunning 1998). For instance, in those industries in which there is a high likelihood of selecting a standard, competitors may decide to cooperate in the development stage so as to prevent rivalry in the commercialization stage. Thus, by sharing costs and benefits through STP firms can maximize their chances of becoming the winning standard.

4) Where the expected benefit of the new area of research is still unknown, the firm will not be interested in investing large internal resources, until the potential benefits are more tangible. Under such circumstances, a risk-reduction strategy through collaboration is most often viable (Mitchell and Singh 1992).

5) Firms are path-dependent, and find it costly to break away from existing routines towards radically new or different concepts. There are additional costs involved in switching trajectories which may impede organizational change and exacerbate the level of uncertainty and therefore economic risk.

6) Non-internal activities, apart from the obvious benefits of exploring new areas and instigating radical change, have the advantage of being a 'reversible' form of investment (Gambardella and Torrisi 1998) which creates a strong motivation to undertake alliances, no matter how much firms may prefer to go it alone. The capital needed is smaller, and the risks are substantially reduced, and in case of failure or organizational crisis, limited damage is inflicted on the primary operations of the firm.

7) Lastly, there are the game-theoretic considerations. As Kay (1997) explains, 'it is necessary to engage in networks with certain firms not because they trust their partners, but in order to trust their partners' (Kay 1997: 215). In addition, there is the follow-my-leader strategy, as originally highlighted by Knickerbocker (1973). Firms seek partnerships in response to similar moves made by other firms in the same industry, not always because there are sound economic rationale in doing so, but in imitation of their competitors.

MNCs need to seek a variety of technological inputs, and this means partnering with not just 'technology leaders'. If this were the case, asset-augmenting activities would remain the exclusive domain of only a handful of firms, and all industries would become oligopolies quite rapidly. It is clear, therefore, that technology leaders actively engage with 'followers' as well. There are several reasons why an MNC should wish to collaborate with a partner which has limited or as-yet-undemonstrated resources to offer. First, because of the nature of innovation, the only way to determine the nature of a potential partner's research efforts is to examine them. One way it can do so is by engaging in some form of mutual hostage exchange, which an alliance provides. Second, even where the partner's resources prove to be of a limited or inappropriate nature, and the alliance is terminated prematurely, information about its former partner's competencies are then available to either firm in future periods, should it require competencies similar to those on offer by its ex-partner. Third, as Hagedoorn and Duysters (1997) have argued, while selecting partners that are well-established players in existing technologies may represent a profit maximizing situation, it is optimal only in a static environment. In a dynamic environment, where there is a possibility of technological change (or even a change in technological trajectories), having ties to a wide group of companies, including companies that have yet to demonstrate their value, represents a higher learning potential. At the technology frontier where dominant technological designs have not yet been determined and several potential options exist, it pays to have a number of overlapping, redundant agreements. It may be optimal to partner with all sorts of companies, even those without a demonstrated track record.

In conclusion, both transaction cost minimizing and value-enhancing reasons underlie most of the behavior of firms, so the two schools may be regarded as complementary to each other (see Madhok 1997 for an in-depth analysis of this debate). Firms would prefer to increase short-term profits through cost-economizing as well as long-term profit maximizing through value enhancement, although this is not always possible. For this reason very few agreements are distinctly driven by one motivation or the other. However, it should be noted that agreements that are established with primarily short-term cost efficiencies in mind (with cost minimizing objectives) are generally customer-supplier networks, while agreements with a more strategic intent where a long-term value enhancement is the primary objective underlies our understanding of STP.

Strategic alliances can be thought of as "an attractive organizational form for an environment characterized by rapid innovation and geographical dispersion in the sources of know how" (Teece, 1992: 20). In other words, the need for a timely and effective knowledge access may well overcome short-term, static (transaction and organizational) cost minimization. Consistent with the view that there needs to be a complementarity between internal and external competence accumulation, there is a mutually reinforcing relationship between intra-firm and inter-firm networks. The relevant implication here is that greater multinational experience can be expected to expand the exploration potential and hence lead to a greater recourse to international STP.

4 Relating STP to internationalization

The international aspect of R&D alliances, broadly speaking, reflects the gradual internationalization of firms. In general, while production activities have gradually been increasingly internationalized, R&D tends to stay significantly 'at home' due to its "sticky" nature (see e.g., Kumar 2001, Narula 2002). Nevertheless, it is worth noting that there has been some growth in the technological development activities of MNEs relative to its level 30 years ago, and its increased internationalization is now due not only to demand factors, generally associated with adaptive R&D in response to specific market conditions; but mainly to supply-side ones (Narula and Zanfei 2005).

Given that R&D activities are knowledge-based, and knowledge tends to be location-bound, locations may offer specialized know-how or capabilities within a specific technological domain (Calderini and Scellato, 2005, Cantwell and Santangelo, 1999). Indeed, it has been shown that a key driver for firms' geographic distribution of R&D activity is the access to knowledge spillovers (Feinberg and Gupta, 2004; Lahiri, 2010). STP – like other asset-augmenting activities— is largely driven by supply side issues. That is, firms seek to utilize immobile assets, which may be either firm-specific and/ or location specific. It is well acknowledged that both location advantages and ownership advantages are idiosyncratic and path-dependent, and the nature of innovatory activities of firms in a given location is associated with its systems of innovation. When a firm wishes to benefit from location-bound assets, it can establish an affiliate in that location, because benefits generally accrue from physical proximity to the firm or cluster. However technology spillovers through collocation can be a highly costly, uncertain and random procedure that requires a long-term horizon, because linkages need to be developed over time. In fields where innovation is very dynamic, a wholly owned subsidiary may not provide a fast-enough response. The use of M&A is even less attractive where the area where the complementary resources sought only covers a small area of the firm's interests, and is generally not possible to do, except in rare circumstances. As a result, in order to tap these foreign external resources and access this specialized technological expertise, firms may find it convenient to ally with a partner located within such economies.

The majority of high-end product development and engineering activities tend to be carried out in advanced Western economies and Japanese firms, because world leaders in knowledge and technology are typically located within developed economies (Arora et al., 2001). This is also true for STP. Technological paradigms are defined on a global basis, because competition is global in nature, and this affects the way in which firms sustain their competitiveness. Firms seek to emulate the technological advantages of leading competitors in the same industry, regardless of their national location (Cantwell and Sanna-Randaccio 1990). Likewise, firms seek to engage in STP with technological leaders in the same industry, irrespective of their national origins (Narula and Hagedoorn 1999).

On the other hand, recent studies argue that innovation activities are increasingly being offshored to developing economies searching for talent, due to the emergence of new geographical technological clusters in developing economies, such as in India or China (Lewin et al., 2009, Manning et al., 2008, Ricart et al., 2011). However, much of this activity is being undertaken through wholly-owned affiliates of major MNEs, rather than through alliances. Besides, a majority of the non-Triad firms are still some distance behind the technology leaders, with a few exceptions. According to NSF (2010), the 50 U.S. alliances with Asia-Pacific companies, excluding Japan, were driven by collaborative agreements with companies headquartered in India (15), China (12), and South Korea (11). As domestic firms from these emerging economies build up technological capability, it is likely we will see a growth in activities. However, the participation of developing countries is rather modest. In 2006 (the latest year for which MERIT-CATI data is available) Japan accounted for as many R&D alliances with US firms as does the rest of Asia combined. The pattern reflects the increasing, if still modest, role of developing countries as hosts for U.S.-owned R&D (NSF 2010). Firms from the East Asian NICs (mainly Korea and Taiwan) and Eastern Europe account for the bulk of the non-Triad partners. Indeed, when one examines the industry and country distribution of STP involving developing country firms, these largely reflect the industrial structure of their economies (Narula and Sadowski 2002).

Even smaller technology-based MNEs are involved in a web of such agreements, and their growing significance raises numerous conundrums (Narula 2002). Firms – regardless of size – must maintain the appropriate breadth of technological competencies, and to do this they must maintain complex international internal and external networks. Such increasingly complex linkages, both of networks internal to the firm, and those between external networks and internal networks, require complex coordination if they are to provide optimal benefits (Zanfei 2000). Such networks are not only difficult to manage, but also require considerable resources (both managerial and financial). Small and medium enterprises (SMEs) have historically tended to rely on non-internal sources more than their larger counterparts and must be more skilful at managing their portfolio of technological assets, but have limited resources (Narula 2002). It is no surprise, therefore, that external technology development is primarily the domain of larger MNCs with greater resources, and more experience in trans-national activity (Hagedoorn and Schakenraad 1994). Managing a web of different types of agreements across borders is not without its price, and highlights the role of transaction-type ownership advantages in the success of the MNE. A dispersion of activities across the globe also requires extensive coordination between them – and particularly with headquarters- if they are to function in an efficient manner with regards to the collection and dissemination of information. Indeed, the management of intangible assets is potentially a core, inimitable advantage of the firm (Madhok and Phene 2001).

4.1 The effect of geographic distance on STP formation

Although R&D alliances may involve lower sunk costs when compared with other governance modes such as M&As, they are also subject to other transaction costs due to the usually uncertain and tacit nature of innovation activities. First, firms face high information costs due to information asymmetries (i.e. high costs of searching and evaluating alliance partners). Second, firms searching for an R&D alliance partner are subject to the risk of adverse selection (i.e. this is the risk of not selecting the optimal partner) (Reuer and Lahiri, 2014). Previous research has demonstrated that firms tend to respond to high information costs and the risk of adverse selection by searching for nearby partners and avoiding partners in distant locations (Rangan, 2000). Selecting spatially proximate partner also offers the advantage of facilitating control, which becomes critical in STP, where misappropriation hazards are high (Li et al., 2008). As a consequence, it has been demonstrated that R&D alliance formation tends to decline with geographic distance (Reuer and Lahiri, 2014).

Nevertheless, there are firm-level characteristics as well as those associated with specific dyads that shape the degree to which geographic distance matters to R&D alliance formation (Reuer and Lahiri, 2014). The value of both direct and indirect prior ties between the exchange partners reduces the negative effect of geographic distance on R&D alliance formation. This is so because prior direct ties between the exchange partners, due to collaborations in the past, as well as indirect ties that they may have through common partners, both help reduce information asymmetries as well as the risk of adverse selection because they will have access to better information on the real resources and capabilities of the potential partner (Zaheer, Hernández and Barnejee, 2010). Indeed, it should be noted that a firm's belonging to a particular network (i.e. both the direct and indirect linkages a firm has with other organizations) may act as a signal of its quality or reputation, thus reducing the risk of adverse selection. Furthermore, both product market relatedness of firms as well as their similarity in technological resources can also reduce information costs as well as the risks of adverse selection, and thus reduce the negative effect of geographic distance on STP.

There is also an extensive literature on the important role that geographical proximity plays in the propensity of firms to form technological alliances from social network theory, economic geography and innovation systems literature (Narula and Santangelo, 2009). These approaches share the emphasis that firms innovative activities show a "spatial stickiness", and for this reason, location is a primary determinant of the competencies a firm possesses (Iammarino and McCann, 2006). These literatures suggest that location (or collocation) has an indirect effect on the choice of partner because of the role of informal institutions in collaborations, which results in firms becoming embedded in relationships that firms have a natural tendency to perpetuate with other collocated firms and organizations. This is so because firms belonging to the same spatially localized social network are "likely to have a greater awareness of the rules, routines, and procedures each follows" (Gulati, 1998: 304), which improves knowledge transfer and reduces the risk of opportunistic behaviors within the network. Indeed, there is evidence that shows that MNEs locate asset-augmenting R&D facilities in offshore locations mainly with the intention of exploiting the benefits that derive from collocation (Blanc and Sierra, 1999; Criscuolo, Narula and Verspagen, 2005). Despite this, it is important to note that not all firms like proximity.

Research has found that there are some firms that, depending upon their competitive position and industry, tend to avoid collocation with the purpose of minimizing undesired knowledge spillovers and leakage of valuable technological assets (Alcácer, 2006, Narula and Santangelo 2009; Shaver and Flyer 2000). Alcácer (2006) found that despite the higher concentration of R&D facilities compared to manufacturing or sales, more-capable firms collocate less than less-capable ones, regardless of the activity because more-capable firms have more to lose than to gain from clustering. For instance, more technologically advanced firms prefer to locate close to universities, and are less interested in locating proximate to rivals, whereas less competitive firms are more willing to collocate with other firms in the same industry (Alcácer and Chung, 2007). Similarly, it has been found that in industries where the knowledge being exchanged is highly tacit, ceteris paribus, the firms' propensity to cluster is higher than in industries where the knowledge is codifiable (Cantwell and Santangelo, 1999, 2000; Iammarino and McCann, 2006).This is so because although the marginal cost of transmitting codified knowledge across geographical space does not depend on distance, the marginal cost of transmitting tacit knowledge does increase with distance (Criscuolo and Verspagen, 2008). Finally, empirical evidence has demonstrated that the firms' preference for clustering or not is highly subject to the nature of the industry structure (Cantwell and Kosmopoulou, 2002) and for firms operating in oligopolistic industries collocating with rivals may not be the preferred option

STP can act either as a complement or a substitute for collocation. STP have the potential to act as a substitute for collocation where firms are not located in the same cluster, while at the same time, these alliances enable firms to directly monitor knowledge exchange with their collocated partners and to access complementary capabilities, thus STP acting as a complement to collocation. Using data for the European ICT industry, Narula and Santangelo (2009) found that STP is complementary to prior collocation of firm's R&D labs. They found that in that type of oligopolistic industry, firms instead of using STP as a mechanism to promote knowledge flows, they strategically use STP as a mechanism to limit knowledge flows and protect competencies.

5 The challenges of STP

Although this chapter has described the potential benefits to of engaging in STP particularly with regards innovation performance (Man and Duysters, 2003), they are notoriously costly in terms of resources, and suffer from a high failure rate. Common reasons for their failure include: Unfulfilled expectations, lack of trust, asymmetry of learning, incompatibility of organizational cultures, unfair or unclear division of control and responsibilities, as well as certain government policies and regulations. Indeed, most alliances have a 70% failure rate, and even where successful, the majority of them last less than 4 years. In a study analyzing terminated research alliances in the biotech industry, Reuer and Zollo (2005) found that only 15% of the terminated alliances examined were successful, in the sense that they achieved their intended outcome (although an alliance may be a success from one partner's perspective and a failure from the other, because firms may learn asymmetrically). Given the strategic, uncertain and knowledge-based nature of the activities involved, these high rates of failure are not surprising. Firms involved in STP face a critical dilemma because they have to maintain the necessary knowledge exchange to achieve the alliance objectives, while at the same time avoid the unintended leakage of valuable technology (Mudambi and Tallman, 2010; Oxley and Sampson, 2004). This dilemma is common to most non-internalized modes of governance, it is more challenging in horizontal alliances. Although horizontal agreements provide opportunities for economies of scale and scope there are also increased possibilities the leakage of intellectual property from one partner to the other. Obviously, these managerial challenges become greater if the agreements are of an international nature. The higher the differences in their national and organizational cultures, language, or institutional environments, the higher the resources the partners need to invest in order to assure communication and control within the alliance.

One of the main managerial challenges firms face when doing STP is associated with how to minimize the risk of opportunistic behavior by the partner. It should be noted that given the characteristics of innovative activities, partners cannot afford complete contracts and strong formal governance mechanisms, which increases the room for appropriability hazards. By appropriability hazards we mean the risk of inadequate uses or modifications of the technology and knowledge transferred, not intended in the contract, and injurious to the transferor. Specifically, the transferor can be worse off under two circumstances. First, when the partner becomes a future competitor; and second, when the knowledge gained by the partner benefits other competitors that are actually clients of the same supplier (Kogut, 1988; Oxley, 1997). Indeed, STP can evolve into a situation that Hamel (1991) calls learning races, in which each partner tries to speed up its learning rate to reach their individual goals first before defecting on the other. Although partners can develop complex contracts to protect their knowledge when self-enforcing safeguards are not effective (Reuer and Ariño, 2007), the partner's notion of the other's ability to exploit the information exchanged beyond the scope of the agreement might deviate its behavior from the theoretically optimal one aimed at maximizing the value of the focal transaction (Khanna, Gulati, and Nohria, 1998). For this reason, despite the positive effects that the development of relationship-specific investments (both tangible and intangible) may have on the performance of the alliance, managers of the firms involved in the STP may opt to under-invest in these investments to avoid misappropriation issues, even at the cost of a lower alliance performance. In other words, as argued by Martínez-Noya, García-Canal and Guillén, (2013), managers have to be careful with how much they invest in the relationship, because although these relationship-specific investments may improve communication and coordination among partners, they may also be a platform for undesired technology transfers and asymmetric learning among partners. However, in relation to this, another factor to be considered is the underlying motivational or strategic orientation of the potential partner. For instance, compared to business firms, non-profits have different motivational or strategic orientation (Das and Kumar, 2010; Li et al., 2010) which means that they have lower incentives to apply the knowledge gained via the alliance to markets or products outside of the agreed-upon scope. This lack of complementary capabilities to commercially exploit the acquired knowledge lowers appropriability hazards, and thus may make them a more suitable partner for those STP in which a high level of tacit and firm-specific knowledge is exchanged (Martínez-Noya, et al., 2013).

On the other hand, another important challenge of STP is related to the higher preference for nearby and known partners, which in some circumstances may limit a firm's innovativeness. As it was previously explained, because firms tend to be location- or network-bounded, and thus either physically or strategically interconnected in a particular organizational network, they may be reluctant to take full advantage of the gains from switching to newer and potentially more valuable partners. This preference for nearby and known may lead to over-embedded relationships (Uzzi, 1996, 1997). As a consequence, instead of embracing new, valuable exchanges with new partners (whose propensity to cooperate is uncertain), firms may prefer to preserve recurring ties with familiar actors (Portes and Sensenberger 1993). However, it should be noted that this preference for the familiar partner can be especially detrimental in a novel context because it has been found that overcoming the limitations of contextually localized search (Rosenkopf and Almeida, 2003), and thus accessing novel resources, is particularly positive for innovation performance when the activities undertaken within the alliance involve exploration such as in the case of radical innovation projects (Nooteboom et al., 2007).

In conclusion, what is clear from previous studies is that external technology development is primarily the domain of larger firms with greater resources, and more experience in trans-national activity (Castellani and Zanfei 2004; Martinez-Noya and García-Canal, 2011, 2012). In this sense, Reuer and Zollo (2005) found partner-specific experience to have a greater favorable impact for non-equity alliances than for equity structures affording stronger formal governance mechanisms. While, their findings also indicated that alliance complexity adversely influences firms' termination outcomes in these alliances. For this reason, in order to extract the maximum value from STP, especially those being international, firms need to have strong technological capabilities so as to be able to act as an efficient system integrator (Brusoni et al., 2001).

6 Policy issues associated with STP

Within policy fora, increasingly there is an acceptance that alliances are complementary to in-house R&D, whether undertaken by firms, or public research organizations (PROs). As discussed in this chapter, R&D cooperation does not replace the need for firms and PROs to undertake internal R&D activities, but it enhances and supports internal R&D. After a period in the 1970s and 1980s where international R&D cooperation was viewed with some suspicion, it is now largely accepted that by and large R&D cooperation across borders can have net positive effects on the economy (see e.g., Vonortas 1997).

Most policy makers recognize that there are cognitive limits to the resources available to any given firm, and the costs of maintaining national innovation systems to acquire world-class expertise in all the different knowledge bases needed in multi-technology products and services is prohibitive. Locations, on the other hand, such as knowledge clusters maintain their overall strengths and specialization over long periods of time, because countries' innovation systems do not evolve rapidly which is why firms are less willing to relocate their R&D abroad (Narula 2002).

In general, firms and PROs in location "A" often cooperate with firms and PROs in location "B" on an ongoing basis as a means to upgrade or even maintain their technological assets. Globalization means that the geographical location or nationality of the potential partner in location "B" is now largely irrelevant, what matters is the quality of their assets. Furthermore, cooperation can act as an alternative to collocation, and sometimes as a substitute to locating

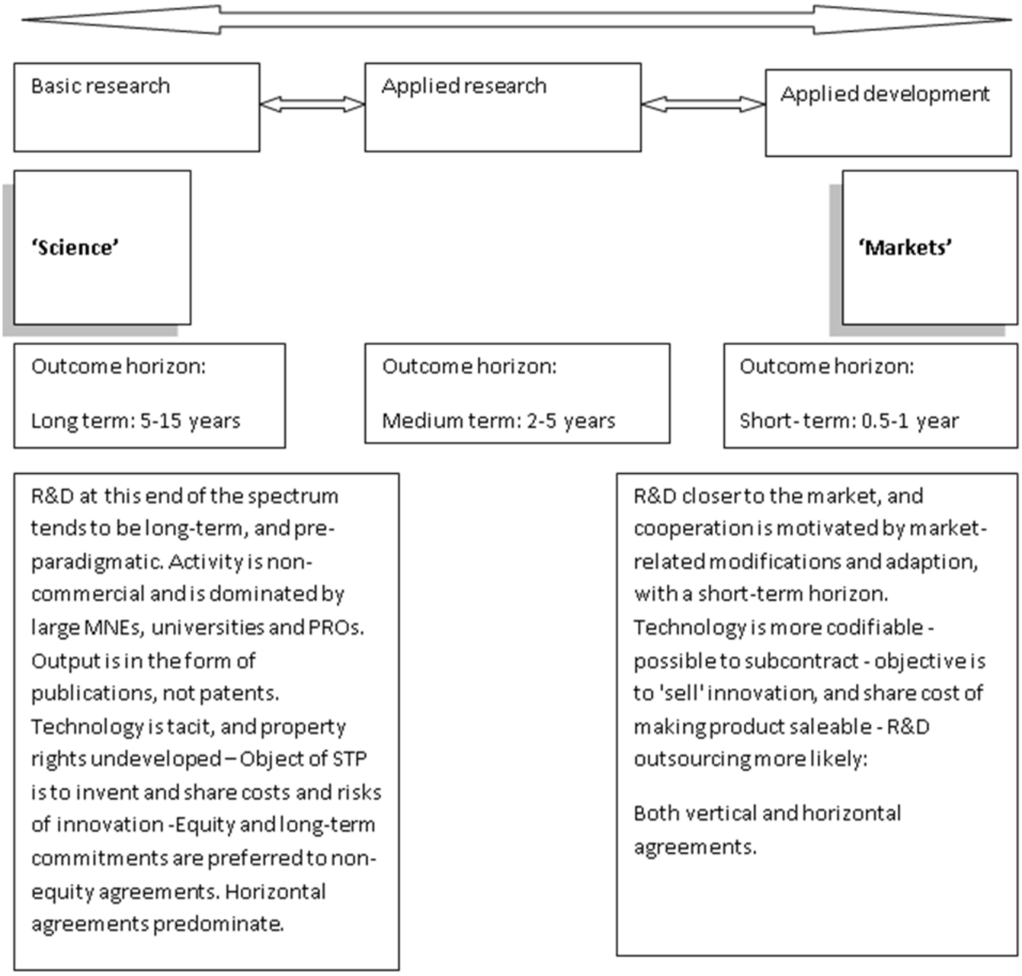
R&D abroad. From a policy perspective this is good, because it counters the dangers of 'hollowing out' (Narula 2003).

Policies to intervene or promote R&D cooperation vary by the distance-to-market of the R&D activity, as well as whether they are horizontal or vertical collaborations (figure 4).

In horizontal cooperation (among enterprises operating in the same industry, engaged in roughly the same kinds and types of value adding activity) the opportunities for economies of scale and scope are maximized, but also provide the possibilities for conflict and leakage of intellectual property from one partner to the other. The cooperation between two biotechnology enterprises or between a biotechnology enterprise and a pharmaceutical manufacturer would be considered a horizontal alliance. These are often largely strategic in nature, and in general occur between large firms and organizations that are leaders in their field. They are commonly used to establish standards, and may often be seen by regulators as anticompetitive, as they involve some degree of collusion.

Vertical collaborations occur among enterprises operating in related industries along the same value chain, where one partner produces inputs for the other. The latter may be a larger enterprise assembling or sub-assembling products from parts and components acquired from different suppliers, including SMEs. It may also be a small systems integrator close to markets and obtaining equipment from larger suppliers. Vertical collaborations are less problematic in terms of regulatory issues, as the partners possess complementary but not competing capabilities and opportunities. Their primary (but not the only) motivation is towards reducing costs. Vertical alliances are especially important within global production networks and global value chains, and are especially common for development (as opposed to research)

Figure 4 Distance-to-market and how it affects STP



Source: adapted and modified from European Commission, 2012

As shown in Figure 4, in new and emerging sectors, technologies are still closer to 'science' than to the market, and in general have a medium- and long-term horizon. Such activity largely involves international research efforts, which are mainly driven by nation states. Firms are likely to under-invest in these sectors, unless there are clear opportunities for commercialization. Governments have several policy instruments to increase R&D investment in these sectors.

One means to do so is by providing monopoly power to the inventors/collaborators so that they may continue to innovate at a socially optimal level through patents or other means. This can be achieved by multilateral collaborative mechanisms, such as consortiums and joint ventures which have the advantage of sharing goals and strategies among the partners. However, where society values maximum diffusion and availability of products at the lowest possible costs, firms will under-invest in R&D when they are uncertain of appropriating sufficient returns. Challenge-driven research is less attractive for firms, especially where the intention is to generate public goods. Key actors from the private sector will only invest resources and take risks of project failure if they can expect a reasonable return in the case of success. On the other hand, swift diffusion of new products and processes is crucial to have a significant impact on global challenges. Diffusion may be hampered if prices for innovations are too high and there are no funding mechanisms to make them broadly available. Another instrument is for governments to directly affect the returns to the innovator by creating a market for the product. Thus the second instrument is for governments to subsidize basic initial research, or to require patent pooling or compulsory cross-licensing of outputs. The difficulty in so doing is that governments may not necessarily select ex ante what the most superior technology is, and it requires a suspension of anti-trust regulations in most cases.

The other instrument is to invest in multi-user research facilities. In this way, the state becomes a participant, and has property rights. Governments can engage as a participant in R&D alliances through PROs or universities. This is especially common in basic research projects, as public research institutes and universities have the human and capital resources to undertake fundamental R&D, or what is referred to as pre-competitive research by the EU. An additional advantage of such participation is that it is better able to monitor the utilization of the resources and act as an honest broker, and prevent the misallocation of funds by commercial (and profit-oriented) partners (European Commission 2012).

In new and emerging sectors, there are often a number of alternative scientific solutions, but firms may not see a viable market (and therefore are reluctant to invest). Governments play the role of market-maker, by creating incentives for private actors to exchange complementary technologies, and by creating a market for the final product that will provide a sufficient return on investment. This may involve PROs who can act as a knowledgeable intermediary between the various parties. Universities play an important role in such alliances.

Although governments are unable to prevent alliances from being unstable, or indeed, from reducing the inherent risk of R&D activity - whether collaborative or otherwise - there is a role for governments in providing information to help identify synergies, complementarities and opportunities, since there are market imperfections in the market for partners. Even where governments do not own the technologies, they can play an important role in match-making firms. Governments can help diffuse the results of basic research output produced either by government research institutes or private establishments to interested parties by creating a sort of 'market place' where potential partners can meet and exchange information. Good government intervention acts to provide 'brokering' organizations specific to industries. Identifying the relevant knowledge producers and knowledge users and bringing them together in a comprehensive and communication-rich network is an important role. Epistemic communities – researchers who share a similar approach or a similar position on an issue and maintain contact with each other across their various locations and fields - create new channels for information and discussing new perspectives (European Commission 2012).

In the case of short-and-medium term initiatives which are closer to the market (see figure 4) these focus on activities that are close to commercialization or already commercialized. In such areas, collaboration has a significant timing element, because commercialization of new products and processes must occur before or close to that of the main competitors. As such the window to establish collaboration and complete the joint innovation activity is quite small – as low as 6 months. Establishing collaboration is a management- and resource-intensive affair, and for short-term collaborations firms prefer to rely on non-equity modes of cooperation which have an important trust element (equity arrangements are slow and cumbersome to establish).

An important role of governments is to assist standard setting, and STP forms a primary means to do this. There is the need to reduce cross-border duplication of activity, especially in terms of multiple (and not necessarily compatible) standards which can be potentially sub-optimal in terms of expenditure on a global basis. However, successful governmental initiatives in standard setting are, in general, the exception rather than the rule, and voluntary standards developed by the main commercial and technological players are more likely to be successful.

Vertical collaborations (customer-supplier) are built on the principle of redundancy, given the high failure rate of collaborations. 'Central' firms within a GPN will make specifications available, and collaborate with a number of similarly qualified suppliers on the same project. The principle is that competition will increase the options of selecting the best technology, given that several partnerships will fail to produce optimal results.

Especially where the technological fields reflect existing research competencies and capacities and maintaining or catching-up competiveness in crucial, a much stronger bottom-up approach is required, because short life cycles means that time-to-market is important. Delays due to bureaucratic issues and high transaction costs can make a huge difference. Here, the priority for firms tends to be on the de facto technological competencies of the partners, as judged by the actors themselves, rather than geographical or national level issues, which are shaped by political imperatives, and can result in suboptimal outcomes from a technological perspective.

Lastly, most policy makers pay special attention to SMEs. One of the policy concerns for states is to increase the participation of SMEs in innovation activities, and specifically to STP, to reduce transaction costs for SMEs to participate. There are high barriers to participation due inter alia to high transaction costs of participating in international STP. These are exacerbated by the bureaucracy of engaging in state-subsidized R&D consortia. Given that R&D time frames operate on a relatively small window – especially development activities closer to the market, and in fast-moving sectors – delays can make the purpose of the collaboration redundant.

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