J Knowl Econ (2019) 10:1341–1361
DOI 10.1007/s13132-015-0310-3

Public-Private Partnership Models for Science, Technology, and Innovation Cooperation

Dirk Meissner[1]

Received: 22 May 2015 / Accepted: 18 September 2015 / Published online: 26 September 2015

Abstract The paper looks at cooperation models for science, technology, and innovation with clear aims at delivering value and progress in these fields. Such cooperation models have been established in various forms in many countries. One special form of cooperation is the public-private partnership which also comes in many different forms. The article is based on the analysis of 20 public-private partnerships located in Austria, Australia, Belgium, Germany, Ireland, Japan, New Zealand, Sweden, and The Netherlands. Public-private partnerships for science, technology, and innovation have various institutional and organizational models. The common central issue of all different models is an interdisciplinary management committee consisting of both academic and industrial representatives which is responsible for the alignment of all partners' interests. In addition, public-private partnerships need carefully developed strategies and well-thought-out contractual basis in line with respective stakeholder communication. Frequently, public-private partnerships are established by a small number of partners but extended at later development stages requiring a seamless and transparent partner selection procedure. Equally important is a sustainable financial agreement which allows mid-term and long-term work by the public-private partnerships. Moreover, in the course of globalization, the regulatory requirements for public-private partnerships in countries and regions are becoming increasingly important. Therefore, in addition to statutory regulations, human resources, scientific excellence, and infrastructure are important determinants for locations which aim at providing attractive framework conditions for public-private partnerships. Finally, it must be noted that two different research cultures meet in public-private partnerships: Synergies have to be found between basic academic research and applied industrial research, and they have to be used for mutual added value. Before establishing public-private partnerships formally, particular attention must be paid to so-called competing values. These must be regulated in a contract, and transparent control and sanction

✉ Dirk Meissner
dirk.meissner@gmail.com

[1] National Research University Higher School of Economics, Moscow, Russian Federation

mechanisms must be introduced. In so doing, the mistrust associated with divergent interests (for example in relation to intellectual property rights) can be effectively prevented from the outset.

Keywords R&D cooperation · Taxonomy of cooperation · Cooperation modes

Introduction

Increasingly internationalized R&D activities are challenging companies to pay more attention to the coordination and integration of related network style activities (Li and Yue 2005). In addition, companies are frequently considering the location-specific innovation potential when assessing locations for establishing industrial R&D facilities (von Zedtwitz and Gassmann 2002; Moncada-Paterno-Castello et al. 2011).

Companies' competitive advantages to a large extent are determined by the skills and know-how embedded in the corporate activities which encourages companies to affiliate their core R&D in close proximity to corporate headquarters (Carlsson 2006). Furthermore, outside technology sourcing has emerged an important element for company R&D (Shin-Horng 2004). Accordingly, companies are increasingly looking for incoming spillovers that are expected to be a measurable value adding result of science, technology, and innovation (STI)-related cooperation with public research institutions (van Beers et al. 2008). Cooperation partners also vary for companies, e.g., in principle companies cooperating with higher education institutes are more likely to address more fundamental research questions which also impose fewer intellectual property-related challenges than cooperation with more applied research institutions does (van Beers et al. 2008). Companies react with the adaptation of their innovation strategies and R&D activities: Instead of being isolated from access to R&D in companies, external R&D is an important contribution to value creation (Vishnevskiy et al. 2015). However, internal R&D is important in order both to absorb external inputs and on the other hand also actively contribute in a specialized area to new insights. This opening of innovation activities is additionally driven by technological changes and the development of new enabling technologies. While these provide new potential for innovation, they increase the complexity and require multidisciplinary competences and skills. Another important aspect is the multivariate use of knowledge and technologies (platform approaches to business). It is increasingly recognized that the success of strategic partnerships depends heavily on specialized actors that strive to add value to the benefit of both parties. In order to gain a focus on core competencies, the common behavior of complementary companies and new forms of cooperation between science and industry are important for achieving the further optimization of value creation and innovation. While in incremental innovations and innovations in non-technological areas (in-house) traditional research dominates, knowledge from external sources may still win out in importance, especially in high-risk, long-term-oriented research and radical innovations. The probability of a successful application and market innovation is significantly increased by the inclusion of scientific research. In addition, faster and more effective innovations will be implemented by target-oriented cooperation along the supply chain. It is estimated that more than half of the companies that rely on full cooperation in R&D and innovation have a better result than their competitors (IBM 2006).

In recent years, an escalating demand for STI infrastructure has been observed on global scale (Mrinalini and Wakdikar 2008; Demirbag and Glaister 2010; Meissner 2014; Gokhberg and Meissner 2013) which is also due to the increasing complexity of technical activities and product development (Chiesa 2000). Moreover, the internationalization of R&D offers opportunities for countries to design an STI infrastructure which allows companies to take advantage of the respective national STI competences and capabilities and the related skills which eventually leads to the generation of positive spillovers for supporting the development of national economies (Baskaran and Muchie 2008). In addition, STI should help cope with social challenges, such as health and environmental problems (Muldur et al. 2006).

The international diffusion of technology has established itself as an important factor for production (Muldur et al. 2006). The greater openness of economies and the accelerated development of technology increase the need for technology-related skills in countries and specific locations (Gackstatter et al. 2014; Proskuryakova et al. 2015). Expertise at the national level enables the innovation base of countries to optimally absorb global developments (UNCTAD 2005). Furthermore, innovation processes are characterized by increased market pressure through globalization, deregulation, and new social needs and changing behaviors for innovation. This creates the need to achieve a higher economic and social return on R&D investment to be temporarily competitive. Companies are also interested in shortening innovation cycles in order to extend the brief period of pioneering advantages. For this purpose, applied research provides an important contribution: It contributes to the development of new areas and enhances competitiveness by shortening the time from basic research to the actual use of the application mainly by intensified targeted STI collaboration.

Public-private partnership (PPP) is becoming an increasingly important form of STI-targeted collaboration. During the last few decades, PPP style collaborations between public and private actors namely in the field of infrastructure and public services were established in many places as an alternative to privatization and state tasks (Advisory Council for Science, Technology and Innovation Ireland/Forfàs 2007). In recent years, additional programs and initiatives in R&D were launched in order to strengthen the cooperation of private and public actors (Audretsch et al. 2002a, b). It is increasingly assumed that application-oriented research collaboration effectively fill gaps in the innovation system, increases the efficiency of government policy and targets, and tackles new social challenges—especially if a long-term multidisciplinary approach is used. Accordingly, STI PPPs emerged (Adams and Jaffe 1996). Therefore, they can make an important contribution to the use of the innovation potential and competitiveness of a location or region (OECD 2005). These assumptions are based on the expectation that technical (technological) progress and innovation lead to economic growth rates, global competitiveness, and social well-being (Link 2006; UNCTAD 2005; Muldur et al. 2006). STI PPP is also considered to be one element of national technology strategies (Edler et al. 2002; Meissner et al. 2013).

The STI PPP is a concept that captures the cooperation between the public and private sectors in various fields at regional, national, or international level and in different sectors such as urban planning, economic development, infrastructure development, R&D and knowledge and technology transfer (KTT), social policy, and environmental protection. Despite, or because of, the wide application of this concept in the field of intergovernmental tasks, fulfillment, and material privatization, there is

no generally accepted definition of it. Therefore, STI PPP is defined primarily as a problem-solving approach that is characterized by a new culture of public-private cooperation (Bingisser et al. 2005). This STI PPP should be understood as a social construction, which can vary depending on the context, objectives, and stakeholders. Thus, the STI PPP that is present in industrialized countries for the time being, is there for dealing with competence and capacity problems of the public sector for the efficient provision of public infrastructure and the partnership's performance of the established complex public tasks. In emerging and developing countries, STI PPP is also used, however, it is used with the aim to provide basic infrastructure. Among the companies' motivations to engage in STI PPP is the ambition to increase tacit knowledge, which is considered especially important for technology system integration and the development of core R&D teams (Gassmann and von Zedtwitz 2003; Asakawa and Som 2008).

In recent years, in particular, the industry-scientific, relationship-oriented STI PPP has emerged (Dearing 2007; Wissenschaftsrat 2007a, b). But even if one only considers STI PPPs that strive primarily for technological innovation, a shortened process for innovation and the R&D sector, there is neither a single nor a narrow definition. There is, for example, the following definition used in the context of research collaboration: "Public-private partnership is an institutionalized form of cooperation between public and private actors, in which both sides contribute resources to achieve complementary goals." (Vogel and Stratmann 2000). Since the individual elements are not specified, a wide range of forms of cooperation can be captured in this definition. Accordingly, STI PPPs are infrastructure-based partnerships between public and private stakeholders with the objective of increasing knowledge and applications in the medium- to long-term prospect, in binding agreements and institutional arrangements that take into account the primary interests of each party, which can perceive risks and opportunities jointly and share and serve the common good in the long term. Against this background, STI PPP research cooperation is therefore defined as

> infrastructure-based partnerships between public and private players aimed at increasing and applying knowledge in the mid to long term in contractually agreed upon institutional setups which take into account the original interests of each party, determine and share risks and opportunities, and serve the long-term common benefit.

Furthermore, the understanding of STI PPP can be extended to also include technology development funds which provide funds for universities and research institutions to support companies with technological capabilities, to leverage the innovative capacity of each region and in the establishment of technological clusters, the innovation of public goods and services to allow for and provide technological developments for the public sector and for social needs.

Irrespective of context, long-term STI PPP research cooperation which is based on confidence building and the optimized coordination of cooperation is best suited to the sustained improvement and strengthening of a national innovation system. National science and research systems cannot stand in the way of globalization. This considerably increases the competition between the individual national science, research, and innovation sites at a global level. In such an innovation context, which is marked by

feedback mechanisms and increased competitive pressure, resource-oriented, long-term and legally established forms of cooperation present a possible efficient and effective response to global challenges. It has been demonstrated in various studies and according to generally accepted expert opinions that such networks can have a supportive effect but that the main innovations come from direct interaction on a personal level. A high level of commitment associated with a long-term focus as well as the establishment of national and international networks are important in doing this. In addition, a sustainable skills base, promotion of interdisciplinary research, and synergy effects are expected by means of the institutional components, which will accelerate the innovation process.

Although the effect of sustainable STI PPPs is often difficult to evaluate and most sustainable STI PPPs have only been set up recently, positive effects can be seen which encourage further intensive initiatives in this direction. A central component in this is the strengthening of KTT, which is often promoted via various KTT offices but would nevertheless be given further impetus, especially as STI PPP research cooperation has a direct influence on KTT and uses sustainable synergies. As sustainable STI PPPs are also targeting the strengthening of applied research and networking, they would be suited to taking direct action on frequently identified shortcomings in national innovation systems. At the same time, it should be ensured that the promotion of basic research will continue and existing (private) initiatives will not be eliminated.

Given this background, the paper focuses on the following research questions:

- How do STI PPPs fit in the overall STI policy mix?
- How can different STI PPPs be characterized?
- Which impact can be achieved by STI PPPs?

The paper develops a general taxonomy of STI-related cooperation in Taxonomy of STI Cooperation section followed by a dedicated taxonomy of STI PPPs for STI in Taxonomy of STI PPPs section. Conclusions section concludes the paper with a summary and discussion of the different taxonomies and their potential and limitations. The paper is the further development of an earlier work by Meissner D "Forschungskooperationen mittels Public Private Partnership—Argumente und Beispiele. Center for Science and Technology Studies, Bern 2007." It advances the empirical work done earlier and further develops the taxonomy of STI PPP.

Methodology and Approach

The conceptual work was accompanied by in-depth analysis of 20 STI PPPs in nine countries which could be identified and classified as STI PPPs. A qualitative approach was chosen for analysis using a structured interview guide of the STI PPPs. European STI PPPs were interviewed personally at the site of the institution; institutions in Australia, Japan, and New Zealand were interviewed by phone. Following the interviews, institution case studies were developed and approved by the interviewees. Interview partners were the leadership of the institutions and also scientists employed in the institutions. The number of interviews per institution varied between three and eight interviews. The institutions cover biomedicine, communication technologies, digital enterprise research, greenhouse gas technologies, health technologies, metals research

telematics, microelectronics, nanoelectronic technologies, optics, polymer research, semiconductor technologies, software technologies, telecommunications, and tribology. For reasons of confidentiality of information, the interviewees and the institutions names cannot be disclosed.

The so developed case studies form the basis for developing the taxonomy and deriving main features of STI PPPs.

Taxonomy of STI Cooperation

As linkages between government, scientific, and economic actors are increasingly seen as an important basis for the performance and innovation of an economy, the various forms of interaction are elaborated upon in order to examine their advantages and disadvantages and their suitability as innovation policy instruments. OECD (2005) differeniates STI PPP into four types according to the different policy objectives, which are not necessarily mutually exclusive:

- Mission-oriented STI PPPs, which ensure the financing of early technology development.
- Market-based STI PPPs, aimed at scientific institutes that help companies build technological competencies.
- Industrial-scientific, relationship-oriented STI PPPs that promote technological developments, products, and services for the public sector and social benefits.
- Cluster/network-oriented STI PPPs, to increase the innovative capacity of individual regions and to develop geographical clusters technologically.

Previously identified forms of political cooperation and the further promotion of entrepreneurial or scientifically initiated forms of cooperation are arranged along three dimensions (Vogel and Stratmann 2000; Becker 2004):

- *Formality*: There is a distinction made according to the depth of cooperation. This cooperation may be configured informally or be contract-based or extend to legal entities.
- *Form of interaction*: The parties may exchange information on research results on a relatively non-binding basis, in collusion, and carry out joint research projects or pool resources.
- *Time horizon*: Cooperation can be ad hoc (i.e., current), medium, or long term.

Furthermore, a distinction can be made between three types of STI PPP according to their time horizon:

- Ad hoc STI PPP with a short- to mid-term focus;
- Test STI PPP with a pooling of resources and mid-term or project-related focus;
- Sustainable STI PPP marked by long-term cooperation with an institutional basis.

In all three dimensions, one moves from non-binding to binding forms that require greater commitment and responsibility. In particular, the depth of cooperation and the time horizon often interact with each other, which means that, for example, closer

cooperation implicitly can bring a long-term cooperation by itself. These three dimensions capture key elements of research collaboration because they illuminate the virtual or the institutional character, the exchanges, and the time horizon. The corresponding expression on these three dimensions is usually deliberately chosen in accordance with the objectives and then determine to a considerable extent the design and operation of research cooperation. If a company is interested, for example, primarily in scientific knowledge, informal networks are sufficient. But if a company wants long-term cooperation with a scientific partner, matching the goals and sharing resources and risks are then to the independent research institution's advantage. With the variety of prevailing forms of interaction, it has to be considered that current contacts or conventional relationships are often classified in terms of client and contractor. They are distinguished in this understanding by a unilateral transfer or by a customer-supplier relationship that is too narrow to be considered an interactive conception of cooperation. The various features of cooperation demonstrate remarkable differences especially with respect to the formalization and time horizon of interaction. Hence, three types of cooperation emerge which are

- Information-oriented
- Action-oriented
- Resource-oriented cooperation.

Information-Oriented Cooperation

The interaction forms that are focused on the exchange of information are distinguished mainly by the transfer activities of expertise and people. Informal networks and related forms are the most important forms of interaction. Information cooperation without legally binding agreements and a low depth of cooperation are mainly for the purpose of exchanging information, but still on a case by case basis, cooperative projects can emerge. With low formal commitment, transaction costs are indeed low, but accordingly, the reliability of cooperation is problematic and highly dependent on the individual circumstances and the commitment of the parties. Therefore, informal networks are advantageous especially in the early stages, when it comes to weighing the possibilities of consensual cooperation and to sharing risks and responsibilities. As can be seen, this can concern short-term, medium-term, and long-term exchange relationships. The duration of cooperation is often vague and dependent on the interests and the behavior of the participants due to the informal nature of the arrangement. Sustainable networks are usually able to create commitment and trust. While short-term cooperations are characterized by a restricted flow of information, it is to be expected that with the increasing duration, there will be stronger commitment. Often, sustainable networks with an open flow of information have common strategies, visions, and goals. A common feature is framework agreements which are developed independently of specific research projects and research objectives. These agreements typically include services supporting the information exchange between participants. The potentially resulting joint projects are governed by specific project contracts. The advantages and at the same time also the disadvantage of this form of cooperation lies in the project agreements: With repeated negotiations, the flexibility of the participants increases, as

they can adjust the scope and ambition of cooperation each time, depending on the expected benefits, and modify the extent of their participation. The added value of framework contracts for the parties arises, therefore, from the flexible and yet common research arrangement. However, with the flexibility, higher transaction costs and lower liabilities go hand in hand. The problem of uncertainty about the extent of cooperation that was already identified in informal networks remains. Moreover, the duration is usually uncertain. Although short-term framework contracts are the exception due to the initial transaction costs, this does not determine whether cooperation in the medium or long term will remain. According to the stabilizing effect of long-term cooperation by repeated agreements or a long-term framework contract arrangement, the liability is higher and the negotiation costs are lower, as the partners know their interests and the ways of working more effectively. Table 1 summarizes the information-oriented forms of cooperation together.

For legal entities, often a relatively stable, binding, cooperative form is typical. This means that the legal status is often accompanied by a certain longevity. The individual members from academia and industry set up an association primarily for the purpose of exchanging information. As responsibilities are weak despite the legal status and the focus, it strongly depends on the members, and problems may arise if the sponsored research is conducted mainly according to economic interests. Or, it can be the case that academic interests dominate, which does not necessarily lead to an industrial end product. In such a case, the discussions and appropriate agreements between science and business, freedom of science, implementation as well as negotiations over access rights to research results are crucial to make research available to companies and to prevent the early publication of the results.

Action-Oriented Cooperation

With longer cooperation time frame, the mutual use of material and human resources becomes more frequent. This is primarily due to not only the facilitation of the exchange of research results but also a common goal and concerted research. Thus, the objectives and strategies are harmonized according to the successive long-term action-oriented partners. Clusters and technology parks constitute the development of informal networks, created as a result of the regional concentration of various organizational networked devices. One such example is the technology parks that lie on or near a university campus and benefit from the academic knowledge base and ongoing research. The close proximity offers opportunities for enhanced cooperation and better networking, which usually leads to sustainable cooperation. The universities expect more effective knowledge development due to the proximity of the company (Link 2006). The actors (companies, universities, public-funded research institutions, and public administrations) participate because of their motivation to create a favorable environment for innovation. The reliability, duration, and effectiveness of cooperation depend considerably on this motivation. Due to the informal nature of this cooperation, the parties benefit from a substantial flexibility and openness to new developments. A greater commitment compared to networking in clusters is reached via contract-based collaboration. These include various forms such as contract research, entrepreneurial initiatives to promote young scientists, patent and licensing, and project-based

Table 1 Information-oriented STI cooperation

Formalization	Time horizon	Cooperation type	Characteristics	Potential	Limitations
Informal	Ad hoc	• Informal/virtual networks	• No legal contract • Short term	• Flexible adjustment possible • Limited investment required	• Low cooperation intensity • High transaction cost • Difficulties in adjusting expectations • Limited information flow
	Mid term	• Informal/virtual networks	• No legal contract • Mid term	• Fruitful basis for trust and confidence development • Flexible scheme	• Commitment and information exchange strongly depended on behavior and interests of parties involved
	Long term	• Informal/virtual networks	• No legal contract • Long term	• Long-term horizon lowers uncertainty • Supports trust building	• No explicit cooperation • High transaction cost
Contract based	Mid term	• Framework contract (narrow focus)	• Rules of conditions negotiated in framework contracts	• Flexibility/involvement depends on stakeholders and projects	• Repeated negotiations for each project
	Long term	• Framework contract (broad scope)	• Legally binding within time frame	• Stable environment	• High transaction costs • Flexibility limited
Legal entity	Long term	• Research funding organization endowments • Association	• Legally binding • Weak responsibilities assigned • Long-term coping mechanism	• Flexibility for parties involved • Subject to negotiations	• Strongly depends on stakeholders • Potential dominance of one partner • Strong need for discussion and negotiations

collaboration. These types of research collaboration are mostly based on fixed-term, precisely formulated agreements according to which the performance of work is either dissolved, extended, or renewed. Thus, they are initially medium- and long-term examples of possible extended forms of cooperation. Under contract research, there is a goal-oriented interaction between companies and a contractor, which is governed by a contract with timing and content requirements. The collaboration, which extends from the exchange of information and to conduct joint (usually spatially separated) projects, is usually characterized by industrial needs. This is frequently offset by companies with patents and licensing agreements. In addition, high transaction costs are incurred in negotiating agreements. In contrast to contract research, sponsored research carries the risk for companies that scientific research provides no usable result in the short term or that scientists publicize the results, due to the lack of or a minimally binding agreement. Table 2 gives a synoptic overview of forms of action-oriented collaboration.

Resource-Oriented Cooperation

Project-related collaboration also goes beyond the forms of cooperation previously described on an action-oriented level, influenced by the client-contractor relationship, as each party brings resources, has a say, participates in the research, and benefits from the results. The cooperation is based on a cooperation agreement, specifying the purpose and the scope of the work, the contribution of resources, and the use of results. Joint research can take place in a shared location or in different locations, but in this case, it is combined in the respective institutions through a regular and clearly regulated exchange. Although project-based collaborations are initially received for a specific (short-term) project, other projects or even a long-term establishment of cooperation may follow. Due to the high degree of cooperation depth, project-specific cooperation is able to circumvent some of the previously mentioned difficulties and prevent unilateral interests from being pursued. With wider cooperation, there are also disadvantages. For example, the negotiation of a cooperation agreement involves significant costs and delays. The limitation of the scope of action requires concessions from all stakeholders. In addition, research is often associated with risks and uncertainties, so results and risks are not in all cases specified in the contract sufficiently in advance.

The termination of project-based cooperation for the fulfillment of a project brings more problems. The company can lose a competitive advantage reached by the project shortly after gaining it, if the research partner uses the acquired know-how in a new project with other companies or in independent work, which is subsequently patented. In addition, liability issues are important. This problem hardly arises in the most binding forms with a legal status. Sponsored research units differ from project-based collaborations due to the fact that resources are pooled in a spatial research unit and the duration of cooperation is not limited. This requires a general and not project-specific definition of the purpose of the cooperation agreement. As the name implies, a dedicated organizational unit does not legally own the assigned resources made available but is embedded in an overarching legal structure. A legal structure is on the one hand important for contracts and grant applications from third parties because only the participating institutions are authorized to sign. On the other hand, the

Table 2 Action-oriented forms of cooperation

Formalization	Time horizon	Cooperation type	Characteristic	Potential	Limitations
Informal	Mid term	• Cluster	• Informal and geographical networked institutions with joint mid-term goals	• Geographical closeness • Strong commitment	• Involvement of actors depends on their interest, no external incentives possible • Free-rider problem: reliability and sustainability of cooperation uncertain • Missing legal rules support flexibility and ongoing adjustment
	Long term	• Cluster • Technology parks	• Informal and geographical networked institutions with joint mid-term goals	• Long-term networking strengthens cooperation and mutual trust	• No controlling mechanisms • No formal agreements
Contract based	Mid term	• Contract research • Company initiatives for supporting scientific/research fellows • Patent and license agreements • Project-related cooperation	• Specified terms of conditions • Contract based	• Goal orientation • Clear structured cooperation	• Projects often determined by needs of industrial partner • Limited scientific freedom • Companies do not build own know-how and absorptive capacities • Difficulties in coordination • High negotiation costs

operating costs are separately allocated to the individual units. Salaried research units are therefore suitable for any legal obstacles concerning mergers, such as laws on higher education. However, they may restrict the legal capacity of the research unit and allow the incurrence of additional administrative costs. By establishing a legal entity and a compelling spatial unit, usually a publicly limited company is designed and stakeholders are involved in long-term commitments. The resolution of the entity is connected to contractual arrangements and high transaction costs. This ensures a relatively long duration of cooperation. In addition, the research organization shall be signed as a legal entity capable of contracts and grant applications. The relatively high transaction costs at the beginning of cooperation and flexibility losses of the parties are offset by additional advantages. For example, this form of cooperation is particularly suitable for complex tasks where at the beginning of the project, all costs and benefits cannot be determined. In addition, such research collaboration is often able to address science and industry-wide topics (Link 2006). Table 3 summarizes the characteristics of resource-oriented cooperation.

The different forms of collaboration show different features resulting in a broad range of potential and limitations. Depending on the initial ambition and motivation of the partners to enter STI-related cooperation, a partnership is designed and established which usually follows one of the described basic models. One special form of STI cooperations is STI PPPs which also come in different shapes.

Taxonomy of STI PPPs

STI PPPs are by frequently more formalized forms of cooperation. The first dimension for developing a taxonomy of STI PPPs is the degree of formalization. The degree of formalization is expressed in the status of the STI PPP and the commitment by partners regarding the STI PPP. Another dimension is the form of interaction that characterizes the STI PPP. This is reflected in the type of partners involved, their goal, location of the STI PPP, and the mechanisms and agreements on sharing risks and chances. Finally, the initial time horizon of the STI PPP agreement allows for distingushing short-term, mid-term, and long-term STI PPPs. Taking these dimensions together, the following STI PPP forms can be distinguished (Meissner 2007):

- Based on a contract, ad hoc *STI PPP* for a short period,
- *Test STI PPP*, which is also based on a contract, but is designed for the medium term
- *Sustainable STI PPP*, which is long term in a spatial unit as a separate legal entity.

Depending on their configuration, the STI PPPs play a different role in the national innovation system. Partners have to make decisions about resources to be introduced in advance. Thus, financial, personal contributions or the provision of infrastructure is possible with varying degrees of intensity and scope. Also, the control or liability is not configured in the same way in each partnership and varies partially even in the time period of cooperation (Vogel and Stratmann 2000). What shape is suitable is the basis of national innovation policy, which determines the potential partners and their respective objectives and interests. The advantages and disadvantages are discussed below, taking into account the possible contexts.

Table 3 Resource-oriented research collaboration

Formalization	Time horizon	Cooperation type	Characteristic	Potential	Limitations
Contract based	Short term	• Project related	• Cooperation contract for specific project • Objectives, resources, and use of results predefined	• Deep cooperation • Adjusted interests • Contract to steer and monitor cooperation activities	• Limited freedom to act for stakeholders • High negotiation costs prior to cooperation
	Mid term	• Project related	• Cooperation contract for multiple successive projects • Objectives, resources, and exploitation paths are negotiated in general—freedom to act	• Considers interest and resources available by stakeholders • Increased freedom to act due to long-term horizon	• High negotiation costs prior to cooperation activities • Difficulties formulating interest and objectives
Legal entity	Long term	• Subsidiary institution	• Unlimited cooperation contract • General rules for cooperation • Stakeholders not bound to legal entity	• Broad objectives • Incentive for substantial investment	• Legal activities limited • Additional administrative expenditures
		• Joint entity	• Stakeholders bring resources into legal entity	• High- and long-term commitment of stakeholders • Resolving entity causes high transaction costs	• High negotiation costs in the beginning • Potential legal barriers

Ad hoc STI PPP

Partners are closely located though spatially separated for a specific, clearly distinguishable project, with a clearly defined cooperation agreement in ad hoc STI PPP. The specific advantage of short-term and binding cooperation exists in the target orientation and low transaction costs. However, since the cooperation is of only limited duration and for a project that is defined beforehand, the impact of this cooperation falls on the national innovation system quickly and selectively. The exchanges and mutual awareness in the innovation network can indeed improve sporadically but are not sustainable. Although technological developments may result from short-term cooperation, a long-term research focus is neglected, sometimes at the expense of short-term business interests. Synergies from the short-term resource pooling are also underutilized.

Test STI PPP

For test STI PPP, cooperation is difficult to specify in advance or is not concrete intentionally, a medium to longer term arrangement is an option that can also provide for spatial cooperation. Institutional consolidation and sharing of resources bring synergy and increase the efficiency of cooperation, not least because of reduced communication costs. In contrast to the sustainable STI PPP, intensive cooperation that does not involve formal legal control problems can occur during the initial test phase. Nevertheless, its impact on the national innovation system and its ability to act may be restricted because of its project-related and non-legal aspect. A long-term, private sector entity can incur less administrative expenses, enjoys more attention, and is more able to strengthen its cooperation and further respond to challenges.

Sustainable STI PPP

In the long-term STI PPP, spatial cooperation plays an important role in an institution, the fair and proper sharing of risks and opportunities, accountability, and the participation of all partners in the decision-making process. Another key feature is the legal status, which indicates that the partnership is not only regulated by contract but is based on an unincorporated entity, mostly as a private limited company that has been created. The legal status goes hand in hand with a greater commitment and often a long-term period of cooperation. Although the negotiation processes that occur ahead of sustainable STI PPP bear transaction costs, they may be offset by the long-term yield of a carefully coordinated partnership with a clear strategy. The open-ended and open-targeted cooperation creates confidence, reduces future transaction costs, and improves risk management, as risks can be analyzed and allocated to the parties. In addition, sustainable STI PPPs, due to their legal status, are in the position to enter into further cooperation agreements. Long-term strategic partnerships make an important contribution to capacity building for both sides and greatly enhance the increase in the scope of knowledge and accelerate the innovation process. A long-term arrangement makes it especially difficult to estimate the risk of consuming pooled resources and complex research questions. In summary, the STI PPP forms can be characterized as shown in Table 4.

Table 4 The comparison of forms of STI PPPs

Characteristic	Ad hoc STI PPP	Test STI PPP	Sustainable STI PPP
Degree of formalization			
Status	• Cooperation contract • Letter of interest/intent	• Cooperation contract	• Legal entity
Commitment	• Somewhat strong	• Strong	• Very strong
Interaction form			
Involved parties	• Minimum one public and one private actor • Open to others	• Minimum one public and one private actor • Multiple actors possible	• Minimum one public and one private sector actor • Equal rights for partners • Number limited
Goals	• Clear, specified objectives • Innovation • Technology renewal	• Partly open goals • Limited project definition • Technological renewal • Shortened innovation process	• General goal definition that is rather unspecific • Substantial flexibility to adapt goals • Innovation • Increase effectiveness and efficiency of R&D • Technological breakthroughs
Cooperation location	• Diverse locations • Virtual networks • Ad hoc resource sharing according to current project • No project portfolio	• Based on existing infrastructure of one partner • Resources allocated to partner that is most suitable for project	• Within an institution • Resources shared (staff, financial resources, knowledge, infrastructure) • Joint decision power and liability
Chances/risk shared	• Result directly applicable • Application part of contract agreement • Application risk specified and shared	• Often no strict detailed regulation • Exploitation rights negotiated after conclusion of project work	• Clear rules of result ownership and risk sharing prior to any work
Time horizon			
	• Short to mid term • Project related	• Mid term • Project related	• Long term

In particular, sustainable STI PPP can play an important role in the national innovation system due to their characteristics. The features listed here interact with and reinforce each other: For example, responsibility, collaborative decision-making, resource pooling, and risk sharing through long-term partnerships and legal liability are encouraged.

Conclusions

The consideration of the different forms of cooperation makes it clear that all forms have advantages as well as disadvantages. Overall, the various forms are trade-offs between commitment and flexibility, which, in turn, also imposes higher transaction costs. Generally, this applies to all forms in which a long-term arrangement is the most favorable for the success of cooperation. In long or repeated cooperation, trust is created and participants can optimize the coordination of their cooperation because they can better assess their mutual interests and resources. Table 5 provides a summary and overview of the potential impact of STI PPPs in general.

Given the diversity of collaboration forms, a question arises about which long-term form is most suitable. However, this cannot be answered independently of the context and the purpose of cooperation. It is also assumed that these do not fit all situations for long-term cooperation. Due to the high transaction costs and uncertain future developments, short- or medium-term cooperation may be preferred in order to avoid delays and high transaction costs and to ensure freedom of action. Furthermore, this also shows the significant increase in cost and efficiency awareness in private sector research activity. Thus, R&D management must increasingly justify activities to the stakeholders who are not part of the R&D organization. According to the motivation for entering cooperation, the form of interaction, e.g., information, action, or resource-orientated interaction, varies accordingly. Information-oriented cooperation, such as in informal or virtual networks, is therefore primary if an exchange of information is improved and mutual awareness strengthened. Resource sharing is limited to the occasional transfer of personnel. This is due to the desired independence associated with the focus on information. Accordingly, the formality hardly reaches its highest expression in the information-oriented forms.

One further advanced interaction form is action-oriented cooperation, which shall conduct the mutual coordination of research and actions and thus is particularly suitable in an environment of existing spatial networks or clearly defined projects and focused topics. In resource-oriented cooperation, the parties launch cooperation primarily with an aim to profit from resources and resulting synergies brought in by both sides. Due to the advanced state of cooperation, which provides for the introduction of the involved resources, the voice and participation in research and the sharing of results, there are no informal resource-oriented forms of cooperation. There is a certain degree of commitment and responsibility required, which is secured by a contract or any legal entity. The fact that these resource-oriented forms of cooperation are long term is primarily explained by their considerable transaction costs and synergies from the resource pooling, which become effective particularly in the longer term. A comparison with the above-described contexts illustrates that the resource-based, long-term, legally established form of cooperation can be an efficient and effective response to the

Table 5 Impact of STI PPPs

		Impact on			Overall impact
		Research system	Innovation system	Impact on foreign actors	
STI PPP type	Ad hoc STI PPP	• Selected technological developments • Potential inspiration for new research fields • Limited KTT	• Timely and focused influence on NIS	• Timely limited impact • Marketing tool to develop external relations and contacts for future cooperation	• Focused support of applied R&D • Contribution to awareness creation for cooperation and exchange • Strengthening project-related research subsidies
	Test STI PPP	• New knowledge/new technologies in high uncertainty research fields • Potential inspiration for new research fields	• Mid- to long-term synergies through geographic closeness and resource sharing • Shortened innovation processes	• International impact of project limited • Contribution to long-term international cooperation more difficult	Influence and decision-making because of non-legal status limited • Incentive for industrial R&D investment and cross-border (entity) collaboration
	Sustainable STI PPP	• Sustainable building of competences • Further strengthening of knowledge base • Support to cross-entity/border collaboration • Suitable for complex research fields • Reduces uncertainty/R&D risk	• Focused and sustainable influence • Clear strategy and long-term cooperation • Synergies • Shortened innovation processes (increased efficiency and effectiveness)	• Well-suited tool to attract foreign partners/foreign direct R&D investment • Suitable for exploitation of national knowledge base	• Strong commitment and long-term influence on interdisciplinary research • Substantial contribution to long-term national and international innovation networks • Strengthening of KTT demand side • Improved integration of science in economy and society

outlined challenges. Before the resource pooling form of cooperation is embedded in the innovation policy debate and the (theoretical) benefits are set forth in detail, the characteristics are discussed below in the discussion of public-private partnership.

STI PPP is expected to increase the efficiency of public and private R&D and thus support innovation-led economic growth and national competitiveness, strengthen the national innovation system leading to the creation of knowledge and technology-based firms, and contribute to the support of SMEs. Complementary STI PPP thus promotes policies that invest in science, R&D, and innovation support, which increase the innovation competencies of firms and strengthen the KTT and relationships within the innovation system.

The high expectations of STI PPP can be traced back to their cooperative tendencies: the solution of complex social problems and the development of new technologies (especially goods with spillover). They require collective action and often invest in several fields of knowledge and technology. STI PPPs can help solve cooperation and free-rider problems by bringing partners together. Trust and networks facilitate further cooperation. Formal or informal, fast and efficient implementation of scientific knowledge in an innovative form, are the main benefits of a STI PPP, besides the network-like structure and the multidisciplinary approach. Also, R&D with social benefits as well as long-term and high-risk projects that need to be stepped up are traditional areas that suffer from underinvestment.

Barriers to innovation and technology and insufficient incentives for businesses arise (Link 2006) because of technical risks, market risks, the excessively high required level of capital intensity, and spillovers of research and thus use by competitors or adjacent industries as well as due to missing or too weakly configured property rights (EU 2005). Innovation policy should support STI PPP because in this context, new key technologies that are central to the national strategy are more likely to emerge (OECD 2005; Hall et al. 2003). In terms of competition policy, however, it must be noted that the incentives for private investment should only be set so that it does not exceed private returns (Link and Scott 2001, 2005). In addition, mechanisms should be left to the parties and the choice of partners.

Eventually it shows that effective STI PPPs inherit following characteristics:

1. *Carefully developed strategy and a well-thought-out contract*: In addition to responsibilities, the dispute settlement mechanisms also have to be clearly regulated in a contract.
2. *Communication with stakeholders*: Information, communication, and decision processes are adapted to suit the partners and their objectives. In addition, importance also has to be placed on personal interaction.
3. *Careful selection of partners*: Common interests, values, and objectives are a basic condition for successful cooperation. Partners have often already been in contact with each other beforehand through a network.
4. *Visible involvement of governments*: The public sector should be involved from the start by means of a control mechanism established in the contract. There should also be an awareness of innovations and the associated risks and activities.
5. *Securing long-term income:* with gains via multiple sources.
6. *Political leadership*: The political leadership must support sustainable STI PPPs both in public statements and statutory regulations.

With the increase of the influence of factors and the numerous interactions in the innovation process, the requirements for innovation policy instruments are growing. Traditional innovation policy instruments and unilateral mechanisms that are lined up, private R&D on infrastructure, basic research and tax incentives, or direct subsidies are increasingly exhausted in their effect, as they are now standard in most countries. In this complex context, knowledge and technology transfer become an interaction model that not only focuses on the one-way transfer of knowledge and technology from science to the economy but also can run in several directions and is in constant mutual exchange. Networks and partnerships act as catalysts. Other spillovers of industry-related partners or other research centers in the network flow easily into the company's own innovations. In addition, the new technologies and the greater emphasis on socioeconomic issues that require a systematic, multidisciplinary and interactive approach, involving both market and societal needs, promotes the cooperation of the various subsystems and all eligible players involved in the innovation system.

For the successful implementation of scientific knowledge and closer cooperation, common interests and complementary skills are required. For this purpose, strengthening mutual trust is crucial. Physical proximity is conducive to essential exchanges in the innovation systems or innovative networks. Often, however, the first differences of opinion between the two systems are overcome. While basic research in particular sees its value as something that it is independent of industrial needs, what it provides for companies to research cannot be transformed into market value, into a short-term benefit. Governments especially can play an important role in the initial phase regulating externalities, coordination problems, and problems of public goods.

Sustainable STI PPPs show a significant impact on interdisciplinary research and the timely transfer of research results into commercial applications as well as the vitalization of regional networks with national and international outreach. Sustainable STI PPPs support the building of trust between the partners, reduce the widespread free-rider problem, and allow a sustainable use of competences to be mutually developed. The bundling of resources and the institutional cooperation allow for the targeted exchange and inspiration between basic and applied R&D and the resulting synergies. One important precondition is the legal status of the institution which is essential for trust building and open exchange between the partners. STI PPPs are an STI policy instrument that complements supply-driven policy instruments especially aimed at enhancing KTT and developing absorptive capacities.

One significant barrier for establishing sustainable STI PPPs are the high transaction costs occurring in their early stages. Moreover, the rather short term focus of companies poses a risk that synergies will not be fully developed and exploited due to the tendency of companies to employ controlling mechanisms in STI PPPs, which are to some extent counterproductive to the long-term nature of building and using synergies.

In conclusion, it can be argued that STI PPPs are complementary measures in the overall STI policy mix. Obviously, STI PPP has distinct advantages for all partners involved. However, because STI PPP combines numerous established STI policy instruments, STI PPPs have to be viewed as horizontal policy instruments that need systemic analysis and preparatory activities involving multiple actors. Eventually, STI PPPs are suitable for linking basic and applied research as well as the different research cultures of the partners.

Acknowledgments The article was prepared within the framework of the Basic Research Program at the National Research University Higher School of Economics (HSE) and supported within the framework of the subsidy granted to the HSE by the Government of the Russian Federation for the implementation of the Global Competitiveness Program.

References

Adams, J. D., & Jaffe, A. B. (1996). Bounding the effects of R&D: an investigation using matched establishment-firm data. *RAND Journal of Economics, 27*(4), 700–721.

Advisory Council for Science, Technology and Innovation Ireland/Forfàs (2007): promoting enterprise-higher education relationships

Asakawa, K., & Som, A. (2008). Internationalization of R&D in China and India: conventional wisdom versus reality. *Asia Pacific Journal of Management, 25*, 375–394. doi:10.1007/s10490-007-9082-z.

Audretsch, D. B., Bozeman, B., Combs, K. L., Feldman, M., Link, A. N., Siegel, D. S., Stephan, P., Tassey, G., & Wessner, C. (2002a). The economics of science and technology. *Journal of Technology Transfer, 27*, 155–203.

Audretsch, D. B., Link, A. N., & Scott, J. T. (2002b). Public/private technology partnerships: evaluating SBIR-supported research. *Research Policy, 31*(1), 145–158.

Baskaran, A., Muchie, M. (2008). *Foreign Direct Investment and Internationalization of R&D: The Case of BRICS Economics. Development, Innovation and International Political Economy Research (DIIPER)*, Aalborg University Denmark, DIIPER Research Series, Working Paper No. 7.

Becker, R. (2004). Gemeinsamen Nutzen sichern Steuerung von Public Private Partnership in der Forschung. *Wissenschaftsmanagement, 2*, 26–31.

Bingisser, S., Bolz, U., Cathomen, I., Oehry W. (2005). *Public Private Partnership – ein neuer Lösungsansatz für die Schweiz*. Zürich.

Carlsson, B. (2006). Internationalization of innovation systems: a survey of the literature. *Research Policy, 35*(2006), 56–67.

Chiesa, V. (2000). Global R&D project management and organization: a taxonomy. *Journal of Product Innovation Management, 2000*(17), 341–359.

Dearing, A. (2007). Enabling Europe to innovate. *Science, 315*(19), 344–347.

Demirbag, M., & Glaister, K. (2010). W (2010): factors determining offshore location choice for R&D projects: a comparative study of developed and emerging regions. *Journal of Management Studies, 47*, 8. doi:10.1111/j.1467-6486.2010.00948.x.

Edler, J., Meyer-Krahmer, F., & Reger, G. (2002). Changes in the strategic management of technology. *R&D Management, 32*(2002), 149–164.

EU. (2005). *Responsible partnering: joining forces in a world of open innovation. A Guide to Better Practices for Collaborative Research between Science and Industry*. Brussels: European Union.

Gackstatter, S., Kotsemir, M., & Meissner, D. (2014). Building an innovation-driven economy—the case of BRIC and GCC countries. *Foresight, 16*(4), 293–308.

Gassmann, O., & von Zedtwitz, M. (2003). Trends and developments of managing virtual R&D teams. *R&D Management, 33*(2003), 243–262.

Gokhberg, L., Meissner, D. (2013). Innovation: Superpowered invention. *Nature 501*, 313–314, doi:10.1038/501313a, http://www.nature.com/nature/journal/v501/n7467/full/501313a.html.

Hall, B., Link, A. N., & Scott, J. N. (2003). Universities as research partners. *The Review of Economics and Statistics, 85*(2), 458–491.

IBM (2006). Innovation und Kooperationsmanagement im Blick. *Global CEO Study* 2006.

Li, J., & Yue, D. R. (2005). Managing global research and development in China: patterns of R&D configuration and evolution. *Technology Analysis & Strategic Management, 17*(3), 317–338.

Link, A. N. (2006). *Public/private partnerships: innovation strategies and policy alternatives*. New York: Springer.

Link, A. N., & Scott, J. N. (2001). Public/private partnerships: stimulating competition in a dynamic market. *International Journal of Industrial Organization, 19*, 763–794.

Link, A. N., & Scott, J. N. (2005). Universities as partners in U.S. research joint ventures. *Research Policy, 34*(3), 385–393.

Meissner, D. (2007). *Forschungskooperationen mittels Public Private Partnership - Argumente und Beispiele*. Bern: Center for Science and Technology Studies.

Meissner, D. (2014). Approaches for developing national STI strategies. *STI Policy Review, 5*(1), 34–56.

Meissner, D., Gokhberg, L., & Sokolov, A. (Eds.). (2013). *Science, technology and innovation policy for the future—potentials and limits of foresight studies*. Heidelberg: Springer.

Moncada-Paterno-Castello, P., Vivarelli, M., & Voigt, P. (2011). Drivers and impacts in the globalization of corporate R&D: an introduction based on the European experience. *Industrial and Corporate Change, 20*(2), 585–603. doi:10.1093/icc/dtr005.

Mrinalini, N., & Wakdikar, S. (2008). Foreign R&D Centers in India: is there a positive Impact. *Current Science, 94*(5), 452–458.

Muldur, U., Corvers, F., Delanghe, H., Dratwa, J., Heimberger, D., Sloan, B., Vanslembrouck, S. (2006). *A new deal for an effective european research policy: the design and impacts of the 7th framework programme*. Springer: European Communities.

OECD, Eurostat (2005). *Oslo Manual—guidelines for collecting and interpreting innovation data*. Third edition; Paris 2005.

Proskuryakova L. N., Meissner D., Rudnik P. B. (2015). The use of technology platforms as a policy tool to address research challenges and technology transfer, *The Journal of Technology Transfer*. 2015.

Shin-Horng, C. (2004). Taiwanese IT firms' offshore R&D in China and the connection with the global innovation network. *Research Policy, 33*(2004), 337–349.

UNCTAD (2005): *World Investment Report 2005*. United Nations New York and Geneva.

van Beers, C., Berghall, E., & Poot, T. (2008). R&D internationalization: R&D collaboration and public knowledge institutions in small economies: evidence from Finland and the Netherlands. *Research Policy, 37*, 294–308.

Vishnevskiy, K., Karasev, O., & Meissner, D. (2015). Integrated roadmaps and corporate foresight as tools of innovation management: the case of Russian companies. *Technological Forecasting and Social Change, 90*(B), 433–443.
No. January.

Vogel, Bernd; Stratmann, Bernhard (2000): *Public Private Partnership in der Forschung. Neue Formen der Kooperation zwischen Wissenschaft und Wirtschaft*. Hochschulplanung, Band 146. HIS GmbH, Hannover.

von Zedtwitz, M., & Gassmann, O. (2002). Market versus technology drive in R&D internationalization: four different patterns of managing research and development. *Research Policy, 31*, 569–588.

Wissenschaftsrat (2007a). *Empfehlungen zu Public Private Partnerships (PPP) in der universitätsmedizinischen Forschung*. Drs. 7695–07; Berlin.

Wissenschaftsrat (2007b). *Empfehlungen zu Interaktion von Wissenschaft und Wirtschaft*. Drs. 7865–07, Berlin.