Introduction: STI Review No. 23, Public/Private Partnerships in Science and Technology

Public/Private Partnerships in Science and Technology: An Overview

Background

Concurrent with the explosive growth in national and international R&D alliances among industrial firms in OECD countries, governments have facilitated and stimulated R&D partnerships between the public research base and industry. This trend has been further accelerated by the recent levelling of public R&D spending as OECD governments rely more on partnerships with industry to leverage R&D resources. Firms enter into R&D partnerships to overcome market failures that result from uncertainty and resource constraints and the inability to internalise significant spill-overs. Private R&D partnerships are thus a market response to market failures that prevent firms from conducting the socially optimum level of R&D. In the same vein, public sponsorship of R&D partnerships is a policy response to similar types of market failures but that are not resolved by market mechanisms alone. This occurs, for example, when the transaction costs associated with R&D partnering are too high to induce collaboration or when the incentives for partnering (e.g. cost-sharing of inputs, appropriation of outputs) are insufficient and thereby result in the rejection by firms of socially beneficial joint R&D projects. Systemic failures that arise from mismatches in the incentives for co-operation among the various actors in the innovation system (e.g. universities, firms, laboratories) can also impede collaboration in R&D and technology, thus leading to lower social returns from public research.

A main appeal of public/private partnerships is that they reduce the risk of failure that results when governments try to "pick winners" through traditional R&D subsidisation schemes. Public/private partnerships entail the competitive selection of participants and greater influence from the private sector in project selection and management, helping ensure that the best participants and projects are targeted. While the direct and indirect benefits of public/private partnerships (e.g. cost and skills sharing) are often touted by industry and governments alike, there are potential costs, both in terms of resources and the opportunity cost of alternative market or policy solutions (e.g. via regulatory measures). The selection of articles which follow in this issue of the ***STI Review*** analyses the development of public/private partnerships in R&D and technology in OECD countries. The rationale for partnerships and the motivations for the public and private sector are examined drawing on evidence from several Member countries, at both the national and the international. Finally, the articles identify problems as well as good policy practices in designing, financing, implementing and evaluating public/private partnerships.

In the area of technology policy, the term "public/private partnership" can be defined as any innovation-based relationship whereby public and private actors jointly contribute financial, research, human and infrastructure resources, either directly or in kind. As such, partnerships are more than simply a contract research mechanism for subsidising industrial R&D. Partnerships can be formal or informal arrangements governing general or specific objectives in research or commercialisation and involve two or multiple actors (e.g. consortia). While informal arrangements exceed formal partnerships, such arrangements take on a more structured context when costs and benefits are directly accountable (either in kind or direct). Formal agreements, as pointed out in the article by ***Shapira and Youtie***, are universal whenever money changes hands. Public/private partnerships are not entirely new. In fact, collaboration between public research and industry has been characteristic of the German research system since the 19th century. In the United Kingdom, collaboration between university departments in science and engineering and industry at the beginning of the 20th century took the form of academics working as consultants to industry, although this type of interaction was later replaced with the development of industrial laboratories. In post-war Japan, partnerships have been an integral part of large government-sponsored industrial technology programmes (e.g. the Very Large Scale Integrated Circuit project between 1975 and 1985) to help Japan catch up in specific sectors. In the United States, even if university and

industry research partnerships can be traced back to the second half of the 19th century, it was not until the Cold War that changes in government policy, led by heightened defence spending on R&D, resulted in increased collaboration between public research and industry. In the 1960s and 1970s, structural change prompted the states to take the lead in promoting collaboration between industry and universities as a means of harnessing technology for local economic development, especially job creation. By the early 1980s, the success of Japanese collaborative R&D and growing competition in global technology markets led to a paradigm shift in the United States, with public/private partnerships becoming a key component of federal technology policy and a tool for improving national competitiveness.

Rationale for partnerships

In many ways, the factors fuelling the rise in public/private partnerships are related to those which drive the increases in private R&D and market-driven alliances between firms. Three of the main factors driving public/private partnerships, in particular university-industry collaboration, are: i)increased speed of transition to the knowledge-based economy; ii)increased globalisation and competition; and iii)budgetary constraints faced by governments and their impact on patterns of funding of university research as well as the higher costs of research in general. To this list must be added several factors that affect the decisions of firms, notably shorter product cycles and hence shorter time horizons for R&D, the outsourcing of generic research including to public research, the convergence of technologies and changes in intellectual property rules governing publicly funded research.

For government, the rationale for promoting partnerships in the context of innovation and technology policy is dual: to correct for the market failure that results in underinvestment in R&D by firms and to improve the "efficiency" of public support to R&D. Market failures associated with underinvestment in technology and innovation stem from problems in private appropriability and from the technical risks and uncertainty that private investors must assume. When the market failure is one of appropriating sufficient returns, the role of the partnerships is to raise the incentive for private firms to invest in R&D (e.g. via intellectual property rights). When it is technical risk (from uncertainty) that precludes private sector investment either by single firms or consortia, government support for collaborative research may be appropriate. In sectors with high economies of scope that prevent firms from fully appropriating research outcomes there may also be a case for public support for R&D. The environment sector, as shown in the article by ***Fukasaku***, is among the most common targets of partnership initiatives given its positive network externalities. Considerations such as national security, economic competitiveness or sustainable development often play a role. As regards the second goal, partnerships help improve the efficiency of public R&D support by eliminating overlapping investments, reducing the time horizons for R&D and stimulating additional spillovers from public research.

The nature of the market failure, however, has a bearing on the rationale and shape of the public/private partnership. In theory, the stage at which the government supports R&D partnerships is where the market precludes a private solution to market failure. This is generally at the pre-competitive stage of technology but, as ***Scott*** discusses, public/private partnership at the commercialisation stage could also be justified if market failures (e.g.in financial markets) lead to underinvestment in the use and application of technology for developing new products and processes. Intense competition in the application of new technology in product markets with high substitutability may also lead firms to underinvest in technology. There is therefore an argument for tailoring government support, such as information provision or financing, according to whether the failure lies in the pre-competitive stage or closer to market. The policy challenge then is to match the amount of government support to the degree of market failure and to design the partnership in a way that allows maximum spillovers without inhibiting incentives for private sector participation.

Approaches to public/private partnerships

At a general level, public/private partnerships can be classified according to the types and characteristics of the actors involved, including: i) university-industry partnerships; ii)government (including laboratories)-industry partnerships; iii) research institute-industry partnerships; and iv) a combination of the above, such as partnerships linking multiple government research institutes to

one another and to industry. With regard to the first category, the article by the OECD Secretariat provides a detailed typology of the various mechanisms for university-industry partnering, from general grants and fellowships through specific contract research, collaborative research and consortia agreements, to training, mobility and networking schemes.

Public/private partnerships can also be classified according to the functional objectives and goals of governments, such as support for strategic research and technology development; improving the mechanisms for commercialisation and technology diffusion; generating spin-offs of technology-based firms. In addition, providing access to innovation financing and training, and stimulating networking among innovation actors have become more explicit objectives of partnerships. From the point of view of the firms, Guy et al. propose four main goals associated with participating in public/private partnerships: knowledge goals; exploitation goals; networking goals; and stewardship goals such as cost reduction and sound R&D management. Although cost-sharing is generally considered a main motivation for partnering in R&D, survey evidence from partnerships in advanced technology programmes suggests that knowledge goals rank highest among participating firms. This may reflect greater heterogeneity among the partners since scale-related issues (i.e. cost-sharing) are more important among similar firms. As regards the technology focus of partnerships, sectoral-based programmes remain important but they are integrating multiple technologies. In her article, Fukasaku examines the integration of energy and environmental objectives in partnership schemes. This further highlights the growing importance for policy makers of linking improvements in industrial competitiveness to the promotion of sustainable development.

There is also an international dimension to partnerships, with cross-border relations increasingly being promoted either as part of national partnership schemes or specific international programmes. The paper by Kemmis reviews Australia's Co-operative Research Centres (CRC) programme, which allows participation from overseas research organisations and firms. This is relevant given that in Australia foreign subsidiaries account for 45% of manufacturing R&D. Another trend in many partnerships is the participation of non-traditional actors such as industry associations, libraries, vocational and technical colleges and even museums. Cannell reveals that collaboration with such non-governmental actors or firms accounted for nearly 10% of participants in the EU's Fourth Framework Programme, compared to around 3% during the Second Framework Programme. Even within government, partnerships increasingly involve co-ordination and co-operation across various ministries and agencies. The implementation of the UK Technology Foresight exercise involved co-operation between several government departments as well as external consultants.

University-industry partnerships

The importance of one form or another of public/private partnerships reflects different institutional structures and research specialisation in OECD countries. In the United States, for example, the predominance of university-industry partnerships reflects the specific national characteristics and embedded structures for (university) research financing. Scientists pursuing basic research in US universities largely depend on competitive grants from extramural funds. In many European OECD countries, university research has traditionally been supported by internal university research funds, although tighter budgets for higher education research have led universities in countries such as Belgium, the Netherlands and the United Kingdom to diversify their sources of funds. Since the 1980s, the share of higher education research financed by industry has increased strongly, especially in Canada, Germany, the Netherlands and the United States. Senker cites threemain factors to explain the increase in university interactions with industry: i) the need for universities to look for non-government sources of funds; ii) the need for industry, spurred by competition and shorter time horizons for R&D, to access a broader science base than available in-house; and iii) the push for greater returns from government support for R&D (e.g. via the commercialisation and diffusion of publicly funded research).

In addition, several OECD countries have made changes in the intellectual property rights governing the results of publicly supported research, and this is partly reflected in the rise in university patenting activity. In the United States, changes in antitrust which allow the formation of private joint research ventures were institutionalised through legislation that allowed universities to

retain title to innovations developed though federally funded research and via new rules that required federal laboratories to facilitate transfer to the private sector. Across the OECD area, governments have helped establish technology transfer and industrial liaison offices at universities, technology incubators, science parks and, more recently, centres of excellence -- all with the goal of increasing efficiency from public R&D spending and diffusing knowledge. The success of these various "bridging institutions" has on balance been mixed. Public funding of these knowledge centres remains an issue as industry participation is insufficient for self-sustainability in the short to medium term (five to tenyears). Among the most successful initiatives are those which have taken an interdisciplinary approach and concentrated on specific technology clusters (e.g. biomedical and information technologies).

- **Government-industry partnerships**

  Government partnerships with industry generally bring together central-government-funded research bodies with consortia of large firms with a focus on pre-competitive or "enabling" research. The most well-known examples include consortia in the area of advanced manufacturing technologies such as microelectronics (e.g. the SEMATECH in the United States, the VLSA in Japan or the JESSI initiative in the European Union). ***Guy et al.*** evaluate the motivations and outcomes of firm participation in government-sponsored advanced technology programmes in Finland, Sweden, the United Kingdom and the European Union. A key aim of government programmes to fund industry consortia, including the US ATP programme is to reduce the technical risks and induce firms to bear the remaining commercial risks which correspond to their market strategies. While partnerships between government and industry consortia may involve universities or laboratories in the execution of extramural research, generally the sponsoring government agency and firms are the main participants.

  Another form of government-industry partnership takes the shape of joint research ventures between government laboratories/centres and firms. Following the privatisation of the government research establishments (GREs) in the United Kingdom, contract research became a source of funds for them as well as for the Research Councils. In Canada, external advisory boards have made public laboratories more applied and client-oriented. In the United States, legislative changes in the 1980s spurred the creation of the Co-operative Research and Development Agreements (CRADAs) which are not collaborative technology programmes per se but rather a mechanism that allows federal laboratories to enter into partnerships with industry as a way to commercialise dual-use technologies. While CRADA-initiated partnerships are mainly considered as promoting technology transfer rather than research, they nevertheless contribute to building the infrastructure for co-operative R&D. Government support for CRADA projects takes mainly the form of in-kind support including staff hours and access to federal laboratory facilities. At the same time, evaluations suggest that government laboratories in general have been less successful than universities in licensing technology. This may be in part due to their late entry and lack of experience in co-operating with industry or to the fact that few laboratory technologies are readily commercialisable and instead require substantial interaction among partners -- well beyond the attribution of intellectual property rights. Laboratories also tend to have less flexibility in partnering with industry given that their objectives are pre-set by agency missions or national R&D plans and the bulk of their funding is generally allocated on a discretionary basis rather than through competition and peer review.

- **Public research institutes-industry partnerships**

  In several OECD countries, industry partnerships with research institutes are more common than those with universities or laboratories. This likely reflects the divide between countries where universities play a larger role in both basic and generic applied research (e.g. Austria, Belgium, Canada, Sweden, the United Kingdom and the United States), including contributing to mission R&D, and countries where public research institutes play a rather substantial or larger role in both basic and applied research (e.g. France, Germany, the Netherlands, Norway). Sectoral or branch institutes are also important in Austria, Sweden and in central and eastern European countries, where many institutes have been restructured to improve co-operation with industry. It should be noted that during the 1980s there was strong growth in the establishment of US research institutes, mainly at universities, which focus on certain industry needs (e.g. robotics for

manufacturing), although the high funding involved has meant that large research institutes have given way to smaller and more specialised types of centres.

In France, the CNRS institutes and specialised research agencies (CEA, INRA) are generally more active than universities and other higher education establishments in partnering with industry. In Germany, partnerships have been characterised by industry collaboration with both universities and applied research institutes such as the Fraunhofer or the Steinbeis Foundation centres. There has been, however, a recent shift in partnership policies away from "institutional-based" collaboration towards project-based partnerships (Leitprojeckte, Bioregio Projects) that involve multiple actors in the innovation system. While public research institutes in France, Germany and the Netherlands have generally benefited from stable and permanent research funding, this situation is changing as institutes rely more on industry support. In Korea, where there is a weak tradition of research in universities, the Government Research Institutes (GRIs) are the main vehicle through which public/private partnerships are promoted. Within the public/private partnerships sponsored by the EU Framework programmes, public research centres and higher education establishments now account for more than half of the total participants (firms account for 38%).

SMEs as partners in R&D

Public/private partnership arrangements are increasingly targeting small and medium-sized enterprises (SMEs), often linking together groups of small firms and multiple public research providers. There are two reasons for this. The first is that successful innovation in firms will increase the number of competitors, leading to improved performance in product markets and consequently generating job creation. The second is that there is a general perception that SMEs face higher risk and uncertainty in technological innovation because of their more limited R&D portfolios and lack of resources such as information, human and financial capital. Market failures may also arise in product markets when the dominant position of large firms or the oligopolistic structure of a given market impede innovations by SMEs. ***Molero and Buesa's*** evaluation of Spain's Centre for Technology and Industrial Development (CDTI), which provides financial support to SMEs, suggests that the financing of research partnerships with small firms may be appropriate in cases where venture capital or other sources of innovation financing are underdeveloped.

The question arises whether the lack of co-operation is due to fundamental incompatibilities such as diverging time horizons -- with small firms focused on specific solutions to specific problems and universities focused on long-term research -- or whether there are institutional and market disincentives to partnerships. Blindly promoting partnerships between SMEs and universities could divert resources away from projects with larger firms that may have potentially higher social and private returns. An approach undertaken by several countries is to broaden public/private partnerships that involve both large and small firms and other actors in the innovation system. In ***Shapira and Youtie's*** analysis of the US Manufacturing Extension Partnerships (MEP) programme, SMEs are linked with various service providers such as federal labs, technology brokers and consultants with support being tailored to different types of firms (e.g. firms in mature industries). The success of such broad-based partnerships, however, presupposes effective channels of co-operation and co-ordination between the different levels of government and service providers. At EU level, a number of special measures have been developed to encourage the participation of SMEs in Community Research partnership schemes which until recently had been dominated by large firms.

International partnerships

While firms have long maintained commercial and R&D alliances, joint research ventures and other forms of market-driven collaboration (e.g. marketing, distribution agreements), governments are also keen on promoting international partnerships. Traditionally, there have been three main objectives of publicly supported international partnerships: i)tackling global-scale issues such as climatic change, oceanography, renewable energy and space exploration (i.e. megascience projects); ii) promoting socio-economic/regional co-operation in R&D through bilateral agreements; and iii) technology transfer and co-operation, mainly between advanced and developing countries and as part of commercial/trade agreements. The Intelligent Manufacturing Systems Initiative (IMS), examined by ***Parker***, aims to set the appropriate manufacturing quality standards and

intellectual property rights for international co-operative R&D. This project illustrates the important role of government collaboration in what initially began as a private/private partnership. A key feature of the IMS initiative is its use of an extensive feasibility study and the development of terms of reference for intellectual property rights. Obtaining support from national governments and tapping into national umbrella organisations made the screening and selection of projects more effective.

At the EU level, various mechanisms exist to promote international partnerships in R&D and technology development. The EUREKA initiative aims to raise the competitiveness of European industry by funding projects which increase co-operation between firms and universities/research institutes in areas of advanced technology. The INNOVATION programme similarly brings universities and small firms together around specific projects. The article by ***Cannell*** reviews the present and past goals of the EU's Framework Programmes for international partnerships which are now moving away from sectorally based research to projects that require a high degree of interdisciplinarity and involve several Member States. Recently, another aim of cross-border partnerships is the promotion of networking among and between actors of national innovation systems (e.g. between international consortia of firms and universities, business-to-business relations).

Problems in designing and implementing partnerships

Framework conditions and intellectual property rights

Framework conditions and intellectual property rights have a direct bearing on the infrastructure for public/private partnerships. At the economy-wide level, tax regimes and regulations affect the costs and incentives for investing in co-operative R&D ventures. Rules on competition (e.g. antitrust) help set the preconditions for public/private partnerships. Relaxing competition policy raises the question of how close to final product market development can co-operation be allowed before competition is distorted. This question is more relevant, however, in highly concentrated and R&D-intensive sectors, and depends on the type and objectives of the R&D partnership. The nature of intellectual property rights also affects the incentives for partnerships as do regulations governing public R&D support in universities, laboratories and research institutes. For example, excessive use of exclusive licensing rules by universities may preclude research financing by firms who see their support benefiting competitors. This raises the issue of balancing the need for a broad diffusion of public R&D with the prerogatives of private firms (increasing private returns). While older technology programmes in the United States have retained title to inventions and licensed their use to firms in exchange for royalties, newer partnerships, such as the ATP programme, grant title to the firms and do not require licensing or in some cases even royalties, for use of the invention, thereby stimulating diffusion. One reason is that the link between public funding of pre-competitive research and the eventual product emerging from the partnership is often unclear.

Within universities, regulations on academic co-operation with industry can promote or obstruct collaboration. Rigid institutional and hierarchical structures that prevent co-operation across university departments and within firms could also weaken the partnership. A main challenge in designing partnerships is accommodating the various objectives of the actors involved. Differences in culture and expectations between universities and industry, including different time horizons for research, must be understood by all partners. The attitudes of management also matter in implementing partnerships: studies in the United Kingdom found that some firms have a higher propensity to partner with public research than others and this may be related to senior management attitudes, awareness and prior contact with public research. Another problem in designing partnerships concerns the effect of R&D assistance on product market performance. In cases of partnerships in concentrated industries there are policy concerns that R&D partnerships may increase product market collusion. Yet, insofar as partnerships aim to achieve other goals beyond cost sharing, such as learning and skills enhancement, this may lead to more intense competition. The risk for conflict between competing firms in the partnership can be reduced by focusing collaborative efforts on the links with suppliers rather than on core products. In fields where technology is changing rapidly, however, partners may diverge in their goals and

expected outcomes, resulting in termination of the partnership or requiring adjustment to the project.

In addition, partnerships are not cost-free. First, they require sunk costs to get started and involve significant transaction costs for both firms and public research actors. Identifying and selecting partners generates time andinformation costs. There are also organisational costs associated with partnering. In pre-competitive partnerships, increasing economies of scale do not always compensate for the additional complexity of managing joint projects. Thus, partnerships are not simply a question of doing more with less but of investing new resources and skills to make research programmes more efficient. In the United States, there has been a move to reduce administrative requirements (e.g. federal accounting methods in reporting inputs and outcomes) which increase the costs of participation to firms. Other problems relate to the changing priorities of managers. At the programme level, there is a risk of conflict between programme managers who are more keen on developing their own relations than linking programmes to other service providers. Public sector and non-profit partners such as vocational colleges may also face pressures from their own priorities, diverting limited attention and resources to the research partnership. Partners must be able to anticipate from the outset: what the objectives are, how and what each partner is expected to contribute, how performance will be monitored and under what conditions partnerships will be institutionalised. Finally, there are potential limits to knowledge transfer and networking from public/private partnerships; some schemes, particularly those at regional level, are not open to firms outside the area (or even foreign-based firms) due to the need for public stakeholders to capture local benefits such as job creation. There is also a debate on whether emphasis on public/private partnerships with exclusive outputs (e.g. patents, licensing agreements) could restrict other forms of collaboration between public research and firms (e.g. joint publishing), thereby limiting diffusion.

Financing mechanisms

How should public financing of partnerships be designed? What form of finance (grants, loans, equity, etc.) is most appropriate for which type of partnership? The answer is that different types of public/private partnerships require different types of funding arrangements at different stages in the partnership (from the R&D to the commercialisation stage). From an economic viewpoint, there are two main questions in financing partnerships. The first concerns the optimum amount of public support and the second, the most effective mechanism for support (grants, loans, in-kind support, etc.). In theory, the answer to the first question would be the amount that lowers uncertainty (which is higher in the early phases of the technology life cycle) and/or inappropriability so that social marginal returns coincide with marginal costs. Another view is that the proportion of public funding should increase with the public content of the research being supported. Although that view is valid, it is problematic because the gap between private and social returns is not necessarily highly correlated with the extent to which insufficient private returns and uncertainty inhibit private investment.

With regard to the most effective mechanisms, the experience in OECD countries suggests some reasons for or against certain designs. Matching funding is often used in collaborative research programmes and consortia, although excessive bureaucratic procedures (e.g. accounting and reporting rules) may exert a heavy administrative burden on firms. At the same time, matching fund requirements as well as competition among programme participants reduce the risk that partnership projects attract only second-rate research projects and less qualified research teams. In the larger US partnership programmes, (which focus on generic technology), grants have tended to be favoured over contracts in some of the new government-sponsored collaborative research partnerships because they accelerate the selection and approval process. Similarly, while recoupment provisions in the event of success have been used, experience has shown that they may potentially undermine the basic intent of the government's cost sharing. Low-interest rate loans are often used in funding partnerships in applied research, but it is important to reduce the risk of moral hazard and opportunistic behaviour by firms. In the case of the CDTI in Spain, the article by ***Molero and Buesa*** reveals that public financing may have been used by some of the larger firms as a substitute for more expensive funds, so that they were able to benefit from a substantial reduction in interest rates.

Ultimately, institutional and funding arrangements for public/private partnerships must be designed so that: i) the best projects, from a convergent social and private perspective, will be chosen; ii) the best private partners will be selected; iii) an optimal sharing of costs, risks and rewards among private and public partners will be found, avoiding unnecessary government expenditures; and iv) opportunistic behaviour will be discouraged and all partners will invest the necessary quality and quantity of resources. While financial arrangements are of critical importance, the share and forms of delivery of public funding are usually defined according to administrative criteria and do not give the government or the recipients the right incentives to make the best use of public money. ***Scott*** proposes an auction-based financing system whereby firms bid for the opportunity to participate in a partnership. The rationale is that firms rather than government know better where to direct research. Under the bidding system, public funding for the R&D partnership is leveraged since the mechanism ensures that the best firms participate at the lowest cost to government. Special mechanisms concerning royalties and cost-sharing are put into place to avoid opportunistic behaviour on the part of government and firms. It is important to stress that the financing mechanisms must be tied to the evaluation apparatus which can signal when government support may no longer be necessary or whether it should be maintained.

Evaluation

Evaluations of public/private partnerships are essential to improving programme design, assessing costs and benefits and generating vital feedback for improving policy. Unfortunately, comprehensive empirical research on R&D partnership initiatives is limited even if a number of case studies on large and high-profile partnerships exist (e.g. VLSI in Japan, ESPRIT in Europe, SEMATECH in the United States). Generally, such studies are more concerned with the characteristics and objectives of participants in partnerships than with the factors driving co-operation or the measurable outcomes including the impact on additionality (i.e. the incremental amount of R&D performed). This reflects in part the lack of an effective methodological framework for measuring the inputs and outputs of the partnership process as well as the timeframe of the evaluations (i.e. short term versus longer term). Partnership outcomes such as patents, or commercial products, services and even jobs may be easily measured in some industries, in others such as services they may take on a more diffuse character yet still contribute to the local economy.

Despite their limitations, evaluations can shed light on the theoretical justification for government support, notably the extent to which market and systemic failures actually justify policy action. Indeed, there is anecdotal evidence to suggest that certain market failures are not as important as would first appear. ***Guy et al***. reveal that for participants in Advanced Technology Programmes, reducing risk was not a main factor for participation. Similarly, while partnering allows for cost-sharing, it is not always a prime motivation for collaboration (although it is in concentrated industries such as pharmaceuticals and aerospace). Access to knowledge, in contrast, may be a main driver, suggesting that market failures from asymmetric information and externalities in human capital development are more significant. Indeed, anecdotal evidence suggests that one of the main reasons why firms participate in partnerships with federal laboratories is access to technical resources rather than for short-term and tangible payoffs.

Also, perceived networking and other intangible benefits suggest that partnerships can successfully address systemic failures. Evidence from ***Shapira and Youtie's*** analysis of the MEP scheme suggest that the focus on partnerships has improved the scale, scope, quality and efficiency of the services delivered to SMEs via the MEP Centre network. Private sector surveys show strong support for partnerships, in particular for projects where industry provides input into project selection. ***Senker*** reveals that partnering associated with the UK's Technology Foresight Scheme improved networking between academics and industrialists. But building networks takes time. Due in large part to the EU Framework Programmes of the past 13 years, international partnerships have now become firmly embedded in the European research landscape. Evidence from the United States indicates that a main benefit for firms participating in partnerships is the development of a process of peer review. Such a process often provides the credibility that helps firms raise capital for commercialising innovative ventures.

As regards the impact of partnerships on research outcomes, the evidence from large programmes in the United Kingdom, the United States and the EU indicates significant leverage effects in terms of the additional R&D generated. One US government study found that CRADAs generated a 3-to-1 return on private sector investment in CRADA projects, but found little evidence of job creation. As regards other goals such as new technological innovations, the impact depends on how close to market the sponsored research lies. ***Molero and Buesa's*** study of the Spanish CDTI centre shows that the majority of the innovations resulting from partnerships between the centre and firms were incremental improvements to existing products and processes rather than radical innovations. There is also the danger that government-led partnerships (e.g. sectoral priorities) could distort the allocation of scarce resources to branches/sectors where there is little comparative advantage.

Conclusions

Public/private partnerships are an integral element of the new paradigm in technology policy characterised by private sector and market-pull co-operative ventures rather than government-led technology-push programmes. For government, the benefits of partnerships between industry and universities, research institutes and laboratories include higher social returns from the exploitation and commercialisation of public R&D as well as a diversified source of funding and improved training of graduates. Besides reducing risk and cost-sharing, partnerships can help firms access skills, monitor new developments and undertake exploratory research in areas outside their core business. However, partnership policies and schemes should not be designed solely on the notion that co-operation between industry and public research is intrinsically "good". Just as industry enters into public/private to achieve specific goals, both tangible and intangible, government and public research institutions should also set clear goals and time horizons for inputs and outputs.

There is a wide variety of public/private partnerships in OECD countries with some forms more prevalent in certain countries, reflecting different institutional arrangements for public support to R&D (including to universities and laboratories). Experience, and the articles presented in this issue of the ***STI Review***, suggest that the type of partnership best suited for a given policy objective will depend not only on the shareholders and their objectives, but more importantly on the type of market or systemic failure being addressed. Partnership programmes must thus be targeted and adapted to the market and institutional environments in which firms and public research partners operate. The size of firms, their sectors and their position on the innovation ladder (e.g. internal R&D capability) also have a bearing on their ability to collaborate with public research. Several OECD countries have undertaken reforms which, on the one hand, improve the framework conditions for private as well as public/private partnerships (e.g. antitrust, intellectual property rights, rules for academic researchers) and, on the other, promote partnerships at local, regional and national levels via indirect/direct supports (tax incentives, competitive grants, in-kind support) according to the type of market failure being addressed.

As regards the design and implementation of partnerships, there is again great diversity in the approaches of OECD countries. University-industry relations are perhaps the most common form of partnership and these take a variety of forms from informal collaboration to targeted contract research, centres of excellence, and knowledge transfer and training schemes. Lessons from various countries suggest that public financing of partnership initiatives should be designed to maximise the contribution of industry through cost-sharing, which increases the market relevance of the project, and to provide incentives for all partners while limiting the risk of capture and dead-weight loss. As well, public/private partnerships should be designed so as not to preclude other forms of collaboration between public research and industry which are important for the diffusion of public research.

Evidence on the outcomes of public/private partnerships for R&D and technology is limited, but case-study and anecdotal evidence suggest that such partnerships -- provided they are properly designed -- can have a leverage effect on R&D as well as generate many indirect and often intangible benefits (e.g. improved networking and flows of tacit knowledge). In this context, informal linkages, which act as a glue to formal agreements and help broaden the sources of external knowledge, have implications for partnership policies which tend to focus more on larger

collaborative ventures. Improvements in the collection of data on public/private partnerships are also needed, not just in terms of their number, sector or geographic origin, but especially concerning the organisation and management of partnerships, their financing mechanisms and outputs. In sum, public/private partnerships can enhance synergies between government missions (e.g. health, defence, environment) and market objectives.

Public/private partnerships are also an effective tool for improving the efficiency of government support to R&D but, as pointed out in several of the articles, it cannot be assumed that industry funding can replace government financing of research, in particular longer-term R&D, which is increasingly critical to the development of future innovations and economic growth.

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