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Technology Strategy of Government and Industry in National R&D Programmes

With Alvey Programme(UK) and ATP Programme(US)*

Heung-Deug Hong**

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Ⅰ. Introduction

A fundamental concern of innovation policy around the world has been the design of programmes that induce substantial and worthwhile R&D with the maximum potential for commercialisation. Industrial collaboration in R&D has been a major feature of corporate technology strategies and government policy initiatives over the last decade (Quintas & Guy, 1995).

Governments are increasing their R&D expenditure in order to improve technological capabilities through national R&D programmes that are designed for firms to take part in. Firms have been participating actively in government R&D programmes in order to develop their technology. It is necessary to study government R&D policy and firms technology strategy in government programmes. Such a research gives insight not only for firms to take an effective technology strategy, but also for policy makers to design and manage the programmes strategically.

Since the 1980s, government and industry in many countries have supported R&D programmes involving research institutes, firms and academic institutes. Examples include Alvey, in the UK, in

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** 국립밀양대학교 행정학과 조교수 (e-mail : msrehhdh@fs1.ec.man.ac.uk)

the US, Microelectronics and Computer Technology Corporation (MCC), US Semiconductor Manufacturing Project (Sematech), Advanced Technology Programme (ATP), in Japan, the TRON, Sigma and Fifth Generation Programmes, and in the European Communities, the ESPRIT, RACE, EUREKA and other programmes.

This paper focuses on an extensive analysis of government policy aspects of R&D programmes, comparing some of the approaches, such as industrial participation and economic spillover strategies, in two national R&D programmes. In particular, firms strategies for cooperating with other actors in R&D programmes and progressing towards commercializing these programme-funded technologies for firms, especially SMEs (small and medium enterprise) funded by these programmes will be discussed. Some have questioned whether SMEs, with limited resources and business experience, will be successful in executing relatively large-scale technology development projects and ultimately in commercializing their programmes. The case study R&D programmes examined in this paper are the UK's Alvey programme, the US's ATP.

First of all, theories related to national R&D programmes, including national innovation system and firms strategies towards programmes are briefly described. Following this, I shall take an overview of each R&D programme and discuss key aspects of firms participation and collaboration strategies using the empirical data.

Ⅱ. National R&D programme and industrial strategy.

Numerous government-sponsored technology innovation programmes have been established since the late 1970s to promote international competitiveness and economic growth through the commercial introduction of new technologies (Brown, et al. 1995). These programme use a wide variety of policy instruments to promote technology innovation, including financial incentives (e.g. grants and low-interest loans); regulatory interventions (including e.g. codes and standards); expansion of public demand (e.g. through government procurement programmes); and information dissemination (e.g. technology transfer networks and clearing houses of information on available technologies).

In general, national R&D programmes may mobilize lots of research actors in national innovation systems to perform cooperatively with one another. Actors in national innovation systems are depicted in figure1. The influences on a national innovation system can be divided into public and private ones. The former include cultural and social conditions, the financial, educational and

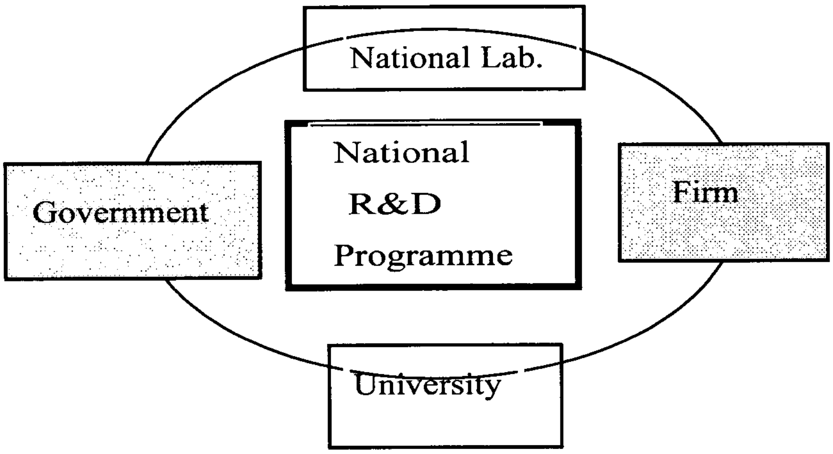
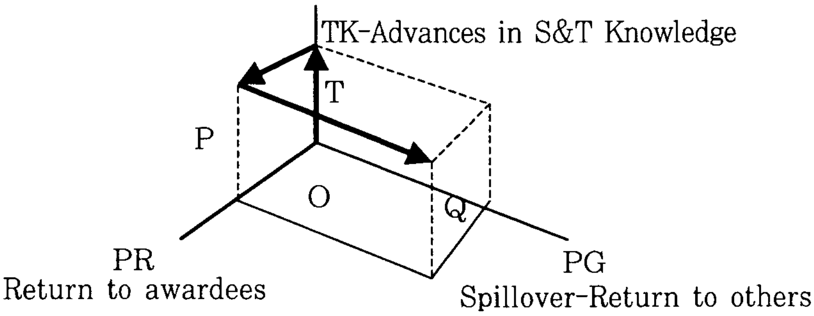


Figure 1 Actors of R&D programme in national innovation system

legal system, including government programme and policy to support scientific and technological research. The latter includes both the organization of production and innovation within firms and the links that firms make either with other firm or with research institutes make in order to acquire external sources of knowledge. There are many arguments why the effectiveness of these links could have a major influence on innovative success (Freeman, 1992; Lundvall, 1992; David & Foray, 1993).

Key characteristics of national R&D programme have been captured by Spender's (1996) three dimensional model of the Advanced Technology Programme. The model, depicted in figure 2, measures on the O-TK axis the success of programme-funded technology development projects in increasing the level of scientific and technical knowledge. It measures on the O-PR axis the net private returns on investment made by programme participants. Thirdly, it measures on the O-PG axis the net spillover returns to others in the economy who benefit from the programme either through consumer surplus benefits derived by purchasing improved or cheaper goods and services, or by utilizing the knowledge derived from programme to generate additional benefits without fully compensating the knowledge generators. The vectors mapped by OTPQ in figure 1 describe a fully successful programme that delivers a combination of high-risk technical accomplishments, positive net private benefits, and positive net spillover benefits.

A firms technology strategy consists of a portfolio of choices and plans that enable it to respond effectively to technology threats and opportunities (Madique & Patch, 1988). Each firm that participates in government R&D programmes confronts several decisions that have to be made; first, which technology will be developed; second, how strongly the programme will



Source: Ruegg T. D. (1998). *The Advanced Technology Program, Its Evaluation Plan, and Progress in Implementation*

Figure 2 Three-dimensional model of national R&D programme.

be aligned with its on-going R&D activities; finally, each firm decides on the amount of external resources of technology and financing that are needed to complete the programme.

R&D consortia provide an effective mechanism for a firm to overcome the shortcomings of market relationships in the inter-firm transfer of information and technology (Ouchi & Bolton, 1988; Warkins, 1991). Warkins(1991) suggests that R&D consortia provide an effective mechanism for firms to overcome the shortcomings of market relationships in the inter-firm transfer of information and technology. Nelson (1984) concludes that R&D consortia are a particularly appropriate mechanism for R&D in the case of generic or enabling technologies.

When a firm takes part in national R&D programmes, it can participate in either a project that is interdependent on solving the technological problems of on-going R&D activities or in a project that is technologically less independent of existing R&D for new business opportunities. In other words, firms may obtain necessary technologies by developing their own commitment or organizing a consortium with other firms, universities, and government funded institutes when participating in government R&D programmes. This cooperative research complements internal R&D activities, and is advantageous in tracking the change of technology. A firm, thus, makes strategic decision on technology source from outside through cooperative research when participating in government R&D programmes. Financial source is important factor in government R&D programmes, because the firm can lessen the financial burden by receiving the governmental fund that encourage the firm's technology development and through joint participation with other firms.

Collaboration in R&D presents both

opportunities and challenges for participants. There are many reasons for collaboration, types of collaborative arrangements, and key factors influencing successful technology and knowledge transfers through collaboration. Quintas & Guy(1995) revealed a diverse expectation of benefits by interviews in the early stages of programme such as the acquisition of technology know-how, an enhanced knowledge base and skills, and the development of tools, techniques, process technologies, sub-systems and even marketable products. Participants also expected benefits through the development of national linkages with industrial and academic researchers, and the leverage of additional resources through collaboration and thus accessing a larger resource base than one firm alone could support.

There are four principal modes of collaboration (Quintas & Guy, 1995).

1) **close collaboration,** with commonly held objectives, interdependent work packages, and working towards an integration of the whole project.

2) **shared parallel work,** such as an evaluation of a number of possible options, e.g. techniques or materials, the division of work between the collaborators leading to shared results and a reduced risk of wasted effort.

3) **loose collaboration,** with work divided into discrete packages or areas of most interest to each partner. Some technology and knowledge transfer is possible, but there is no final bolting together of the whole.

4) **no real collaboration,** participants working independently with minimal contact.

In general, R&D collaboration had become necessary because of the pace of technological change and the increasing scale and complexity of systems, requiring ever increasing competence across a widening range of discipline (Teece, 1986, Quintas & Guy, 1995). This has led firms to seek access to technology from external sources in order to reduce the cost of R&D, to share resources, to participate in the development of industry standards, and to reduce risks and uncertainty in the R&D process. Firms participating in such R&D programmes use public funding for additional work: that is, for R&D which would not have occurred in the absence of government support.

Ⅲ. Government strategy for the national R&D programmes

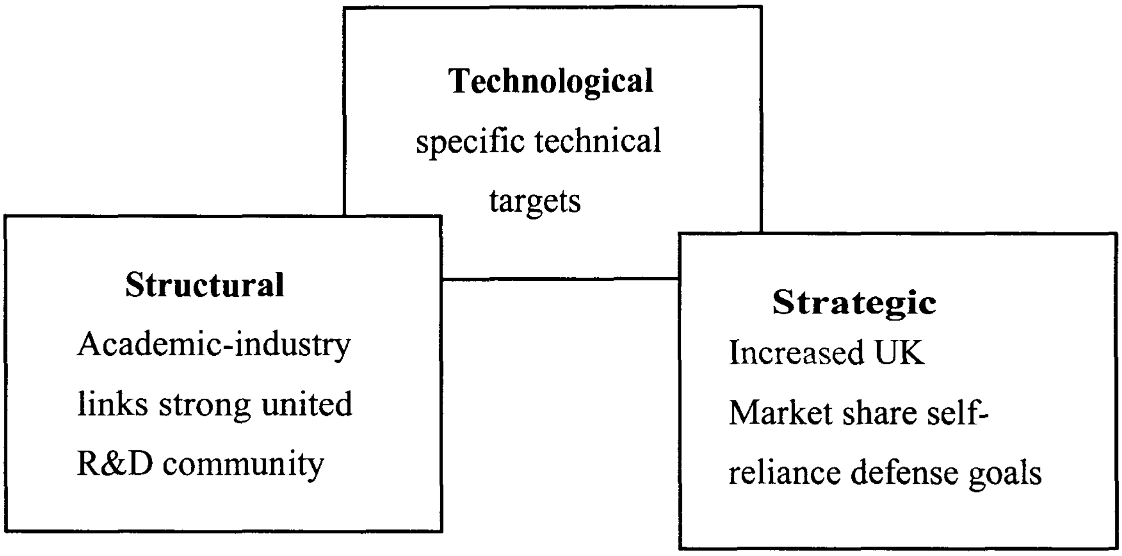
1. Alvey programme (UK)

The Alvey programme was the UK governments response to a report by a committee which was set up to consider the implications of the announcement by Japanese of their fifth generation computing project in 1981(Georghiou, 1991). Alvey results from government recognition of declining IT supply-side competitiveness, market failure to support longer-term R&D, the success of previous Japanese R&D programmes and threat of another.

The Japanese strategy galvanized action in many countries by threatening a quantum leap to next-generation computing. In the UK the announcement coincided with concern over the competitive failure of much of the IT supply industry. The UK IT sector had been in relative decline for over a decade, performing especially poorly in the computer, consumer electronics, package software and semiconductor markets.

For political and economic reasons, Alvey was largely confined to pre-competitive R&D; i.e. R&D which is distanced from the market, being focused on generic or enabling technologies rather than the development of final-use products targeted on specific markets. Here enabling technologies are mainly process technologies that enable a multiplicity of product markets to be satisfied downstream (Quintas & Guy, 1995).

Alvey allowed firms to hedge their technological bets by facilitating the pursuit of insurance R&D. This benefit-accelerated R&D, maintained R&D and deepened knowledge-suggest that firms used the programme to enhance and support pre-existing technological strategies in



Source: Georghiou L. (1991). *Evaluat'ng Alvey-Britains National Information Technology Porgramme*. Manchester Statistical Society.

Figure 3 Aims and objectives of Alvey programme addition to entering new R&D areas.

Alvey ostensibly attempted all three types of government support programme identified by Nelson (1988): basic research; programme tied to procurement needs; programmes aimed at improving the competitiveness of a particular industry. The fundamental aims of Alvey (Georghiou et al, 1988) were:

1)to increase the competitiveness of the UK IT suppliers;

2)to ensure a measure of self reliance in key technological areas for commercial and defence purposes;

3)to strengthen the R&D base of UK by rationalising and uniting fragmented resources, and particularly by encouraging academia and industry to work together;

4)to achieve specific technical targets in each of the enabling technology areas;

The structural objectives were more readily approached. Firms had to collaborate with others and/or with academic researchers in order to qualify for funding. Collaboration was expected to help promote structural change through the establishment of R&D communities, linkages between firms, academia and government research institutions, and the rationalisation of research efforts.

Over the 5 years, Alvey supported 198 collaborative R&D projects, each project lasting 2 or 3 years on average. A total of 115 firms, 68 academic institutions and 27 government research laboratories participated.

Table 1 Industrial recipients receiving over 1 million pounds

Firm	No of participations	Total funding(000s)
GEC	66	22945
ICL	37	14720
Plessey	39	10470
BT	31	9030
STC/STL	31	8815
Ferranti	18	8645
Racal	9	4435
Software Sciences	7	3230
Logica	16	2325
SDL	10	1730
British aerospace	7	1630
CAP	2	1065
Hewlett Packard	2	1050

Source: Georghiou L. (1991). Evaluating Alvey-Britains National Information Technology Porgramme. Manchester Statistical Society.

How do collaborative R&D projects fit into corporate and business-funded R&D activities? The first point to acknowledge is that the formulation of Alvey programme strategy itself involved industrial contributors. UK IT companies GEC, Plessey, ICL, Logica, Inmos and British Telecom were represented in the Alvey Report. For some of these firms, a close relationship existed between their own corporate R&D strategies and the development of technology strategies within the Alvey programme.

2. ATP programme (US)

The ATP was created by the Technology Competitiveness Act of 1988 and received its first budget in 1990(Ruegg, 1998). The programme was designed specifically for the purpose of assisting United States businesses in creating and applying the generic technology and research results necessary to (1) commercialize significant new scientific discoveries and technologies rapidly, and (2) refine manufacturing technologies

The ATP rule emphasizes that ATP funded technologies must be enabling in that they must offer a wide breadth of potential application and form an important technical basis for future commercial application, they must be high value, because when applied, they offer significant benefits to the U.S. economy and high risk technologies.

Enabling technologies are further categorized as pathbreaking, infrastructural and multi-use.

1) Pathbreaking technology is described as inducing revolutionary change in existing fields or opening up new field of activities.

2) Infrastructural technology is described as supporting the R&D, production, and business of entire industries.

3) Multi-use technology is described as having many distinct applications.

The ATP defined high-risk technologies as "technical challenges that display significant recognized uncertainty of success, where success will dramatically change the future direction of technology and its market impact ".

To accomplish its mission, ATP awards are made through fair and rigorous competitions. The multi-years ATP awards are made both to individual companies and to joint research ventures comprising of two or more companies, often in combination with universities and non-profit research laboratories. Most single company awards actually resemble joint ventures in their involvement of their organizations. However single-company awards are limited to two million dollars and three years, while in the case of joint-venture projects there is no mandated limit on the amount of award, and the period of performance is limited to five years instead of three. From 1990 to 1997, the ATP made multiyear awards for a total of 352 projects, including over 100 joint ventures, and involving more than 800 participants. The framework of the programme architecture is as follows:

1) Eligibility requirements

Eligibility requirements are primary constituent elements of a programmes architecture. The following questions help us examine this feature more carefully. Who is allowed to participate and what are the rule regarding that participation? Are only firms allowed to apply? Or, must firms pair with a university or non-profit organization? Who is allowed to be the lead organization in a project? Does the programme require collaboration or are applicants left to decide?

The ATP requires for firms to lead projects. Whether in a single proposal project or a joint-venture project, firms are the lead organizations, with other companies, universities, non-profit organizations, and federal laboratories as their partners (Chang, 1998). At the same time, the ATP encourages participation by other kinds of organizations, including universities and government laboratories. The main objective of this aspect of eligibility is to strengthen the R&D effort and build the knowledge base. More than 250 universities were among the over 800 organizations participating in the 352 projects funded by the ATP from 1990 through 1997. Although the ATP does not force collaboration between firms, or between firms and universities or non-profits organizations, leaving the decision of how best to structure their project to applicants, it has some built-in factor to encourage partnering.

One incentive to partnering is provided by the rules governing financial assistance. By limiting the amount of financial assistance to $2 million for direct project costs for single-proposal projects (prior to 1998, companies regardless of size were required to cover their indirect cost only, but starting with the 1998 awards, a large company may receive assistance of no more than 40% of total project costs with a maximum of $2 million, while non-large companies are required to cover all of their indirect cost. The ATP encourages companies to partner in a formal way to solve large problems.

2) The nature of the research

The ATP fund research that can lead to the creation and rapid commercialization of high-risk, enabling technologies that have the potential to generate economic and technical opportunities that can lead to broad-based benefits for the nation.

3) Technical scope

The ATP takes a hybrid approach. It offers both general competitions that are open to all technologies, applications and ideas and focused programme competitions which fund interlocking sets of projects that are focused on achieving pre-specified technical and economic goals.

4) Public-private financial arrangements

The ATP is designed with a cost-sharing requirement. The ATP requires the award recipient to cover all indirect cost of the project, with the exception of large business that must cover a minimum of 60% of total project costs. The ATP requires at least two-profit industrial members in a joint venture project to contribute more than 50% of total project costs.

Ⅳ. Industrial strategy in the national R&D programmes

In this chapter, the main aim is to provide an analysis of industrial participation in the programme in order to further the understanding of collaborative R&D processes within a firm. Central questions concern the relationship between participation in the programme of collaborative R&D and wider company processes-the strategies and drivers of participation, the dynamics, mechanisms and organization of collaboration, and the processes of technology transfer, knowledge assimilation and application within a firm.

1. Alvey Programme

The Alvey programme was largely formulated in terms of the market failure argument, namely, market mechanisms fail to ensure that adequate resources are allocated to R&D(DTI, 1988). Firms business and technology strategies may change radically over a period of 5 years, and a firm may decide to pull out of a business area, e.g. STCs decision to withdraw from the merchant semiconductor business, or GECs withdrawal from the CMOS semiconductor market, both of which happened during the Alvey programme.

The additional benefits of Alvey are therefore not only to be found in wholly new R&D areas, but in added achievements in existing areas: accelerating R&D, broadening and deepening knowledge, building critical mass (Quintas & Guy, 1995).

1) Alvey participation strategy

Companies strategies toward Alvey can be differentiated in terms of the way they constructed their Alvey project portfolios. Some firms set out to attain a coherent group of interested Alvey projects; others had much more ad hoc, uncoordinated approaches that resulted in relatively isolated and disconnected projects. The way in which firms constructed their Alvey portfolios is related to the characteristics of the different technology areas, to the structural position and strategic orientation of R&D within companies, and to the sizes of projects. Also Alvey projects having no connection to firms existing R&D activities had poor achievements compared with Alvey projects linked to in-house R&D activity.

2) Industrial collaboration in Alvey

Interview with Alvey project managers at the end of the programme found that the most commonly cited reason for collaboration (78% of project managers) was the acquisition of the complementary expertise, including familiarity with technology, techniques or access to equipment (Guy et. al, 1991). The second most common reason, cited by over a quarter of project managers was to comply with Alvey funding criteria. A key indicator of the success of collaboration engendered by Alvey is the extent of subsequent participation in similar collaborative R&D. 22% of industrial teams felt that Alvey has had a positive effect on their entry into international collaborative R&D programmes.

Another important point is the ability of firms to acquire knowledge and technology via collaborative R&D. 46% of industrial participants thought that Alvey had been very important in enabling them to access academic know-how, compared with 22% feeling the same about know-how from industrial partners. The extent to which a firm can internalize technology and knowledge and how far these benefits can be transferred internally within the firm

Table 2 Follow-up R&D of Alvey industrial participants

	Percentage of teams in each technology area with each follow-up action					
	SE	IKBS	VLSI	MMI	LD	Total
No follow-up R&D	28	19	31	35	45	30
One firm only	17	19	22	12	27	18
With Alvey academic partners	33	26	19	38	36	29
With Alvey industrial partners	11	11	9	15	27	13
With new partners	22	41	25	35	45	30
Team numbers in sample	18	27	32	26	11	114

Rows 3-5 are not mutually exclusive
Source: SPRU final Alvey questionnaire

and combined with firm-specific competencies remain crucial questions.

2. The ATP Programme

All organizations funded by the ATP are 37% of small firms, 31% are medium-sized firms, 21% are large firms (Fortune 500 or equivalent), and 11% are universities and non-profit organizations in partnership with industry in joint venture projects 11%. Figure 3 provides comparative analyses of project goals and the expected commercial advantage for small firms and all organization.

Applications pursued by both small firms and all organization more frequently involved product applications than process applications, with an even greater focus on product applications in the case of small firms. Regarding the types of commercial advantages expected, over one-third of applications were considered new-to-the-world solutions, and for most of remaining applications, performance advantages over existing products were more important than cost. Small firms had more aggressive performance and cost goals. With respect to key aspects of ATPs mission - technical challenge and significant opportunities for economic spillovers - a greater percentage of small firms than of all than all organizations

Table 3 Project goal and expected commercial advantage

		All organization	Small firm
Planned commercial application	No of application	808	359
	Average per firm	2.08	2.35
Type of Commercialization expected	Manufac. Process	27	22
	Product	64	69
	Service	9	9
Commercial advantage expected	New solution	36	37
	Performance	18	20
	Cost	7	4
	Performance & cost	35	33
	Other	4	6

Source: Powell J.W. (1998). Small Firm Experience in the Advanced Technology Program. NIST.

as a whole appear to be attempting to achieve ambitious project goals.

Table 4 illustrates some of the differences in strategies for commercialization planned by small firms compared with those planned by all organization. Licensing to other was a primary strategy for 38% of small-firm applications, compared with 27% of applications planned by all organizations. Thus, a large number of applications reported by small firms did not necessarily reflect unrealistic demands on their limited resources.

Table 4 also shows plans for strategic alliances for commercialization. Not surprisingly, forming alliances with

Table 4 Strategies for commercialization

		All organization	Small firm
Licensing to others	Primary	27	38
	Secondary	19	19
	Possible	35	32
	N/A	19	11
Producing product/service in House	Primary	62	62
	Secondary	12	18
	Possible	10	10
	N/A	16	10
Adopting process for In-house use	Primary	27	22
	Secondary	13	12
	Possible	16	13
	N/A	44	53
Forming alliances With customers	Primary	23	29
	Secondary	14	19
	Possible	30	30
	N/A	33	22
Forming joint Production alliances	Primary	14	20
	Secondary	24	16
	Possible	34	29
	N/A	36	27
Forming alliances With distributions	Primary	14	21
	Secondary	12	17
	Possible	26	30
	N/A	48	32

Source: Powell J.W. (1998). Small Firm Experience in the Advanced Technology Program. NIST.

customers was the most common primary and secondary strategy for small firm applications. This strategy was cited as primary or secondary for 48% of small firm applications but only 37% of all applications. Overall, firms seem to recognize the need for supply chain linkages in at least some applications.

The formation of collaborative R&D relationships among companies, universities and other research organizations is a specific part of ATPs legislated mandate, and collaborative R&D is cited frequently in the literature as a key strategy for success. Table 5 summarizes selected findings for collaboration experiences. A High percentage of both small firms and all organizations believed the ATP was responsible to a great extent for the collaborations. The specific effects of collaboration were regarded as consistently stronger by small firms than by all organizations.

A higher percentage of small firms than all organizations cited a significant effect of collaboration in identified customer needs (55% compared with 43%), stimulating creative thinking (78% compared

Table 5 Collaboration experience on projects

		All organization	Small firm
Collaboration experience	Yes	82	76
	No	18	24
Was ATP responsible?	Great extent	67	66
	Moderate extent	22	26
	Slightly	7	4
	No/not all/not sure	4	4
Identify customer needs?	Significantly	43	55
	Moderately	29	24
	Little/none/not sure	28	21
stimulate creative thinking?	Significantly	72	78
	Moderately	25	17
	Little/none/not sure	3	5
Attract capital investment?	Significantly	15	20
	Moderately	19	28
	Little/none/not sure	66	52

Source: Powell J.W. (1998). Small Firm Experience in the Advanced Technology Program. NIST.

with 72%), and attracting investment capital (20% compared with 15%).

Ⅴ. Conclusion

Drawing on the experience of the national R&D programmes, this paper provides an analysis of government R&D strategies through national R&D programme and industrial technology strategy, especially the conduct of collaborative R&D, at the level of the participant firm in the R&D programme.

The ATP requires firms to lead projects. This requirement reflects the prime programme goal that the funded research be followed by the accelerated commercialization of new products and processes derived from developed technology. The rationale underlying ATPs focus on being industry-led is that economic benefits only result when the new technology is transformed from the knowledge stage into new and better products, processes, and services for users.

In contrast to the ATP, the Alvey programme does not require firms to take the lead role. Alvey requires there to be a collaborative effort between firms and universities. One reason for this requirement is that it is a great assurance that university ideas are taken up by UK industry and not foreign firms, that is, the programme promotes technology transfer out of the universities. By requiring firms and universities to work together, Alvey programme designers are not giving firms a stronger voice, but are encouraging universities and industry to collaborate in proposed research projects.

The ultimate aim of most national R&D programmes is to strengthen the nation economically by encouraging new technology development, whereby government facilitates rather than directs. A programme that requires collaboration between firms and universities, or national laboratories may do so with the goal of transferring knowledge created by universities or national laboratories to industry. They may be more focused on the diffusion of existing new technologies created by universities and national laboratories and less concerned with the particular interests of industry. Continuing collaboration with academic researchers is considerably more common, and collaboration with new partners is even more pronounced. The effectiveness of an R&D programme is also dependent on how well it interacts with other initiatives in order to achieve synergy effects or leverage effects in support of technology transfer (Inno & Gmbh, 1996).

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