A New Lexicon and Framework for Analyzing the Internal Structures of the U.S. Advanced Technology Program and its Analogues Around the World*

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Abstract

Analogues of the U.S.'s Advanced Technology Program can be found in many countries around the world. These government programs provide financial assistance to firms and other entities to develop innovative technologies in the conviction that these developments will contribute to future economic strength. For political and economic reasons, these programs tend to be complex and intricate in their design. No informed evaluation and comparison of such programs can take place without a clear understanding of their internal structures. This paper analyzes the anatomy of such programs and constructs a vocabulary for understanding program design choices. It identifies and discusses a representative sample of important program design features—eligibility requirements, the nature of the research, technical scope, the selection process, and public-private financial arrangements—and provides examples of national programs embodying alternative design choices. This paper should interest policymakers, program administrators, program evaluators, and others involved in program design, management and evaluation.

Introduction

Analogues of the U.S.'s Advanced Technology Program (ATP) can be found in many countries of varying sizes and economic maturity around the world. These government programs provide financial assistance to firms and other entities for research to develop innovative technologies that underlie national economic growth. The technologies that are created with the help of such programs are expected to improve the competitive strength of organizations in terms of new capabilities and enhanced productivity, and lead to new products, processes, and services that will benefit the national economy and increase the number of high-wage jobs. These programs tend to be complex and intricate in their designs owing to the complex political and economic goals to be served. However, little attention has been given to understanding the internal structures and workings of such programs. Although a body of literature exists on comparing national civilian technology policies and strategies, not much work has been done on analyzing how particular programs operate or on comparing and contrasting the design of such programs. As a result, our understanding of these specific national programs and their comparative similarities and differences is limited. Without a lexicon with which to analyze and frame our understanding of these programs, our knowledge remains superficial and our comparisons faulty.

This paper attempts to help fill this knowledge void. It analyzes the anatomy of such programs and constructs a vocabulary for understanding program design choices. An informed debate about such programs can only take place when we have a firmer grasp of their internal structures. Others have noted the importance of examining program details. When speaking of ATP-like programs, Spender argues that "The program's details are vital given their intrinsically political judgments about the relationships between the public and private sectors, the fact that any government involvement in the private sector's markets needs justification, and that its design invites a clash of concepts about how innovation happens and a technologically-driven economy works" (Spender 1997, p. 51). Hill has also considered specific features of the ATP in regarding its design and opportunities for improving the program for greater success (Hill 1998).

This paper identifies and discusses a representative sample of important program design features—eligibility requirements, the nature of the research, technical scope, the selection process, and public-private financial arrangements—and provides examples of national programs embodying these design choices. When considering all programs, some have been in existence longer than others, providing opportunities for relatively young programs, like the ATP, to learn from the experience of older programs. Similarly, there are opportunities for older programs to examine how younger ones are designed for creative ways

*This paper is drawn from a draft report, "A Multi-Country, Binational Comparison of the ATP and its Analogues," by the author, prepared for the National Institute of Standards and Technology. The draft report covers additional program features of a number of programs in different countries.

Journal of Technology Transfer Vol. 23 (2): 67–73.

of doing things better. It is hoped that this new lexicon and framework of analysis will help us improve our understanding of how these programs operate. This paper should interest policymakers, program administrators, program evaluators, and others involved in program design, management and evaluation.

Building a Lexicon and Framework for Understanding Program Architecture

The following section identifies and discusses a representative sample of important program design features and provides examples of national programs embodying alternative design choices. Table 1 provides a summary view. (For a treatment of additional design features, see Chang 1998.) For each design feature, the ATP's approach is first described, followed by a discussion of how other programs have alternatively approached the same design feature.

Eligibility Requirements

Eligibility requirements are a primary constituent element of a program's architecture. The following questions help us examine this feature more carefully. Who is allowed to participate and what are the rules 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 program require collaboration or are applicants left to decide? Answers to these questions reveal the design choices such programs have made, with respect to eligibility, and suggest concerns that underlie that decision.

The ATP requires for-profit firms to lead projects. Whether in a single-proposer project or a joint-venture project, firms are the lead organizations, with other companies, universities, non-profit organizations, and federal laboratories as their partners. This eligibility requirement reflects the prime program goal that the funded research will be followed by accelerated commercialization of new products and processes derived from the developed technology. By requiring projects to be industry-led, the ATP is deliberately designed to provide firms the incentive to pursue follow-on commercialization activities of project results with private sector funds. The rationale underlying ATP's focus on being industry-led is that economic benefits only result when the new technology is transitioned from the knowledge stage into new and better products, processes, and services for users (e.g., a new, improved medical treatment that is actually delivered to patients who then benefit from its use.)

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 125 universities are among the over 800 organizations (excluding subcontractors and informal partners) participating in the 352 projects funded by the ATP from 1990 through 1997. University participation is encouraged by requiring that projects press the state of the art. Many companies must turn to university research laboratories to extend their technical capabilities. Although the ATP does not force collaboration between firms or between firms and universities or non-profits, leaving the decision up to applicants in how best to structure their project, it has some built-in influences 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-proposer projects (prior to 1998, companies regardless of size were required to cover their indirect costs only, but starting with 1998 awards, large companies may receive assistance for no more than 40% of total project costs—not to exceed $2 million, while non-large companies are only required to cover all of their indirect costs), the ATP encourages companies to partner in a formal way to solve larger problems. By capping the number of years of assistance to three years for single-proposer projects and five years for joint-venture projects, the ATP further encourages formal partnering to undertake longer-term projects. By setting stringent criteria for integration across technical and business project objectives, the ATP encourages companies to partner to meet the need for strength in multiple technical fields, markets, and knowledge diffusion. Joint-venture projects, defined by the participation of at least two, for-profit companies performing the research and sharing in the costs, are not limited by the amount of assistance provided, but more than half of the total project costs must be cost-shared by industry.

The LINK Scheme, an ATP counterpart program in the United Kingdom, began operations in 1988, the same year as ATP's authorizing legislation. LINK is aimed at enhancing the competitiveness of U.K. industry and the quality of life by supporting pre-competitive research in areas of strategic importance to the U.K. economy. In contrast to the ATP, LINK does not require firms to take the lead role. LINK requires project proposals to be a collaborative effort between firms and universities. One reason for this requirement is greater assurance that university ideas are taken up by U.K. industry and not by foreign firms, that is, the program promotes technology transfer out of the universities. Partners must come to an agreement on who will lead the project and in practice, project leadership is split 50-50 between universities and firms. By requiring firms and universities to work together, LINK program designers are not giving firms a stronger voice, but are intentionally encouraging proposed research projects to have equal relevance to both industrial and academic partners. LINK's design may increase the likelihood of technology transfer from universities to industry, and increase the diffusion of project results via academic publication. The question is whether the companies will be focused on rapid commercial progress.

Policymakers in other countries have made yet other

Table 1. Comparative features of the ATP and its analogues*

	U.S. Advanced Technology Program	Canada Technology Partnerships Canada (TPC)	E.U. Framework Program	Finland Tekes	Japan Teiankobo	U.K. LINK Scheme
Program Year of Launch	1988-Present	1996-Present	1984-present	1983-Present	1997-Present	1988-Present
Mission	Stimulate economic growth and accelerate the commercialization of technologies	Encourage economic growth and create jobs, specifically to help co's develop new products for export	Develop European S&T capability and meet other objectives	Stimulate economic growth	Creation of new industries	Enhance the competitiveness of U.K. industry and the quality of life
Technical Scope (open to all techs? pre-selected list? or hybrid?)	Hybrid General competitions are open to all; focused competitions fund specific tech areas. All techs must be high risk and enabling	Hybrid Pre-selected aerospace and defense; environmenta and enabling techs (open to techs that can create new industries)	Pre-selected list	Pre-selected list	Hybrid Energy and environment; and industrial S&T (open to techs that can create new industries)	Pre-selected list
Who Leads?	Industry	Either industry or university	Industry	Industry	Industry	Either industry or university
Nature of Research	Beyond basic science, prior to product development	Close to product development	Beyond basic science, prior to product development	Beyond basic science, prior to product development	Close to basic science	Mainly, prior to product development.
Formal or Informal Selection Process?	Formal	Formal	Formal	Formal	Formal	Formal
Cost-share Requirement	If single proposer, 100% of indirect costs (if large business, minimum 60% of total project costs). If joint venture, greater than 50% of total project costs	Typically 70-75% of total project costs	Minimum 50% for industry. 0% for university partners	Minimum 50% of total project costs	N.A.	Minimum 50% of total project costs

*This table is taken from a draft report by Chang, "A Multi-Country, Binational Comparison of the ATP and its Analogues," prepared for the National Institute of Standards and Technology and planned for publication in September 1998.

program design choices with respect to eligibility. For example, the European Union's Framework Program for Research and Technological Development which was launched in 1984 provides financial assistance for pre-competitive research to trans-European consortia. Each project must have a minimum of two independent partners based in two different member states. Projects that promote coordination or collaboration between member states are given greater consideration. The addition of a geographical element to the eligibility criteria reflects the program's political objective of creating a united European research community.

A program that is designed to allow only for-profit firms to apply as the lead organization, in either a single proposer project or a collaborative project, may be trying to ensure that the research being pursued is relevant to industry. Moreover, by placing a firm at the helm a program may be seeking more commitment from the proposing firm in bringing technologies developed during the project into commercialization. In contrast, a program that allows or encourages universities, research institutes, non-profit organizations, or government laboratories to be the lead applicant may perhaps reflect the belief of its architects that universities are as capable as firms in creating new technologies for the marketplace, or perhaps, it may reflect a greater interest in knowledge creation and less concern about future commitment to commercialize new technologies. It may have less concern about research results being exploited by firms in other countries instead of its own. A program that requires collaboration between firms and universities, or firms and 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 in universities and national laboratories and less concerned with the particular interests of industry.

The Nature of the Research

The kind of research a program supports reveals the nature of the problems it is addressing. Along the research spectrum, a program may fund research that is closer to basic science (without attention to potential uses), or it may fund product development work (there may be serious barriers to bringing technologies to market), or it may fund somewhere in between these two ends of the continuum. It may fund applied research to develop enabling technologies with some anticipated applications as well as many potential uses not yet envisioned. It may focus on the research interest of a single firm or group of firms, or it may be more concerned about effects that will likely extend beyond the direct award recipients. It may focus on easy-to-assimilate, incremental technologies, or revolutionary technologies that entail radical changes for their users. Choices such as these reveal a balance by the program of public interests and private interests, of feasibility and risk, of deliberate goal seeking and unknown outcomes.

The ATP funds 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. The ATP does not pay for product development or other expenses related to commercialization; and it does not fund projects that are geared to creating new knowledge for knowledge's sake without an evident pathway to commercialization. It is designed to create innovative technologies which have the potential for widespread commercial application with benefits extending far beyond the direct award recipients.

Like the ATP, the U.K.'s LINK Scheme funds long-term, enabling and generic research to enable and accelerate the commercial exploitation of science and technology, leading to new products, processes, systems, and services. In contrast, Technology Partnerships Canada (TPC), a Canadian counterpart program to the ATP launched in 1996, funds nearer-to-market projects. The TPC program provides funding for activities related to the development and demonstration of products, processes, and technologies (including research, development, technology commercialization, sustaining technology, quality management, and technology integration and acquisition); pre-production to develop production capabilities; and studies related to potential projects or the identification and assessment of strategic technology opportunities.

Technical Scope

The technical scope of a program refers to the technologies that qualify. It takes the category of research discussed above as given (e.g., "pre-competitive," "enabling," "high-risk") and goes one step further in asking what technologies within this category of research are eligible for funding (i.e., within the program's scope). Among the possibilities are that a program provides funding to eligible organizations for research to develop technologies of their own choosing with little involvement of government. Another is that technologies/topic areas/themes are set in advance by legislators or program administrators. Hybrids of the two provide other options. For example, eligible applicants might have the option to propose project topics either in technology areas of their own choosing or in pre-selected areas. As another example, eligible applicants might propose whatever they like, but program administrators might screen them based on public-interest criteria.

The ATP takes a hybrid approach. It offers both general competitions which are open to all technologies, applications and ideas, and focused program competitions which fund interlocking sets of projects that are focused on achieving pre-specified technical and economic goals. Focused program ideas in the ATP are generated from industry input in the form of white papers and are further developed in public workshops and meetings held by

program managers. Only program ideas that best meet selection criteria that are designed to accomplish the program's mission—high technical challenges, broad-based economic benefits, industry commitment, and the necessity of ATP support—are selected as new programs. Project proposals for focused program competitions are evaluated against published selection criteria, as are project proposals submitted to general competitions. By concentrating funding in particular areas while allowing proposals that fall outside the technical scope of these areas to be submitted to general competitions, the ATP tries to ensure an open door to all excellent ideas, while concentrating its investment impact in certain areas which have the potential to deliver large national benefits. Examples of focused programs are photonics manufacturing, catalysis and biocatalysis technologies, tools for DNA diagnostics, tissue engineering, and adaptive learning systems.

Canada's TPC program focuses its funding on three main technology areas—aerospace and defense; environmental, and enabling technologies. Like the ATP, the TPC program employs a hybrid approach by pre-selecting three areas, the last of which offers firms the chance to propose research topics that are broader than the other two. This last area, enabling technologies, is open to proposals that can create new industries or show the potential to transform and strengthen the basis of competition in whole industry sectors, including proposals to develop advanced manufacturing and processing, advanced material processes and applications, biotechnology, and advanced information technologies.

In contrast to the U.S. and Canadian hybrid programs, the U.K.'s LINK Scheme favors pre-selected themes. LINK has 58 programs focused on particular technology or market areas that provide support for research of strategic importance to the U.K. economy. These programs are categorized under the main headings of food/agriculture, electronics/communications/IT, biosciences/medical, materials/chemicals, and energy/engineering. Each program typically receives financial support from a number of Government Departments and Research Councils. Since 1995, new LINK programs have been responsive to priorities identified under an initiative called Foresight which brings together industry, academia, and government to identify long-run trends in markets and technologies in the United Kingdom and emerging opportunities for U.K. industry, and to suggest possible courses of action to take to benefit from these opportunities.

Another example of a program taking the pre-selected approach is Finland's TEKES, or the Technology Development Center. It began operations in 1983 and aims to help firms develop technologies that can lead to internationally competitive products, production processes and services. At the beginning of the program, a committee was set up and proposed twelve nationally important areas to improve Finland's technological capabilities. Since then, further programs areas have been driven by industry. Technology areas are decided after workshops and conferences are held by TEKES to gather and develop ideas with industry. The program areas link firms in specific industrial sectors with the aim of raising their collective technological know-how. Program areas have included planning and manufacturing technology for electronics, computer-integrated manufacturing technology, construction technology, mining technology and pulp and paper technology.

A program that is open to all technologies may be more responsive to where industry wishes to go, and more flexible in responding to changes in the marketplace. It may be more able to invest its resources in areas that most need government assistance at the moment. A program that limits its funding to pre-selected technologies may be less flexible in responding to changes in the marketplace, but may benefit the nation by concentrating a critical mass of funding in specific technology areas that meet particular goals. In making its selection of technical areas, a program may consult with industry to identify areas that are important to them to help ensure that follow-on commercialization will occur. However, as Kelley points out, the disadvantage with this approach is two-fold: it "presupposes that the agency has the internal staff expertise to assess what it learns from these interchanges" and it "may tend to favor technical areas of interest to [well-established groups within the private sector R&D community that have a greater capability to engage in such dialogue with a government agency] over those proffered by new or less well-organized groups." (Kelly 1997, p. 323). A program that takes a hybrid approach in defining its scope of activity may be able to take advantage of the positive features of both while limiting the disadvantages of each.

The Selection Process

When considering programs in all countries, selection processes by which projects are chosen for funding vary across programs from highly structured to informal. The following questions are useful in examining this feature more carefully. Is the selection process formalized? Is a peer-review process used? Are projects selected according to publicly available criteria? What are the criteria? Do they include, for example, technical and/or economic merit, geographical or regional balance, collaboration between organizations, political affiliation, or other goals at the discretion of program administrators?

The ATP has a formalized, peer-review process for selecting projects. Selection criteria and application guidelines are published in a booklet called the Proposal Preparation Kit which is updated, re-issued periodically and widely disseminated. A selection board composed of technologists from government laboratories and agencies, business experts, and economists is established for each announced competition. Each project proposal is reviewed for the strength of its plan to pursue high risk research, its potential in delivering broad-based economic benefits to the nation and plans for diffusing results and bringing technologies developed during the project to commercial

fruition, the proposed organizational structure to accomplish project goals, commitment to carry the research through to commercialization, and experience and qualifications. The board chooses projects that score highest against these published selection criteria to receive financial assistance awards. The board does not consider geographic balance, political concerns, company relationships with staff, or other factors in its decision making process—only the "official" selection criteria.

The European Union's multi-annual Framework Program, which sets out the E.U.'s main scientific and technological objectives for a five-year period to tackle problems more effectively at the European level than by individual member states, encompasses several thematic programs. Applicants submit proposals to specific program announcements. Like the ATP, there is a step-by step published guide that provides applicants with general information on the submission and selection process. Proposal evaluators are given a set of formal, established criteria against which proposed projects are reviewed. Although detailed selection criteria differ across programs, there is a set of common selection criteria which are similar to ATP's in the focus on scientific and technical excellence, diffusion of technical results, and impact on the economy, but unlike the ATP there is no required plan for future commercialization. Moreover, there are two other important differences. The Framework Program requires transnational collaboration, as mentioned earlier. In addition, the Framework Program provides funding to projects which are aimed at serving goals other than the creation of new technologies, including training and mobility of researchers, and standards and measurements. Furthermore, other considerations such as the R&D priorities of member states are also taken into account, reflecting the political concerns to which the Framework Program must be responsive.

A new program in Japan called "Teiankobo" which translates into "proposal-based, new creative technology research and development program" was established last year in several ministries, including the Ministry of International Trade and Industry (MITI), and has different research foci depending on the ministry in which it sits. MITI's Teiankobo is administered by the New Energy and Industrial Development Organization (NEDO), a public corporation attached to MITI. Like the ATP and the Framework Program, MITI's Teiankobo also makes its selection process and criteria formal and publicly available (in Japanese). In NEDO's public request for proposals, guidelines are provided for applicants. These guidelines state that a screening committee established within NEDO will evaluate proposals submitted against specific screening criteria which are composed of five elements: fundamental, original, and innovative research; ripple effects on industry, the economy, and society; international significance with Japan taking a leading and guiding role; appropriateness of the plan and schedule of goals; and ability to implement the project. The guidelines also state that NEDO will consider the screening committee's deliberations to make the final selection of projects.

An approach that relies more on established, formal selection criteria may provide greater assurance that projects will be selected for their merit. Projects that are selected according to criteria other than technical and/or economic merit may deliver on these other objectives, but possibly at the cost of good technical and economic results—as would probably be the case if the selection process were not based on peer review, but on, for instance, political favoritism.

Public-Private Financial Arrangements

Cost-sharing arrangements are another constituent part of a program's architecture. What are the financial arrangements between the government and participants? Is the government providing a grant or a loan? Is the government a minority investor in the project or a majority investor? A program may be designed to provide all the costs of a research project or require that award recipients pay some portion.

The ATP is designed with a cost-sharing requirement. For single proposer projects, the ATP requires the award recipient to cover all indirect costs of the project, with the exception of large businesses which must cover a minimum of 60% of total project costs (direct and indirect)—a requirement that is effective beginning with 1998 awards to encourage large businesses to join in formal collaborative efforts. The ATP requires at least two for-profit industrial members in a joint venture project to contribute to the cost-share requirement of greater than 50% of total project costs.

Many analogues to the ATP have similar cost-sharing arrangements. U.K.'s LINK Scheme and Finland's TEKES both require a minimum of 50% cost share. The E.U.'s Framework Program requires at least 50% cost share from companies while university partners have all their costs paid by the government. Canada's TPC program, however, requires a higher cost-share typically between 70% and 75% of the eligible project costs, but not lower than 67%. The TPC program's higher cost-share requirement is understandable because it funds nearer-to-market projects, as mentioned earlier, and expects to recover its investment generally through royalties once a project is complete.

By setting or not setting a cost-share requirement, program administrators can influence the type of projects proposed. For example, by requiring some level of cost sharing, programs may find greater commitment on the part of the award recipient to carry out the project to term and pursue subsequent commercialization since their financial stake in the project provides them with a stronger incentive to realize a return on their investment. However, the larger the cost share required of industry—let's say, larger than the government's contribution like Canada's TPC program—the more likely firms are to propose projects that can deliver earlier commercial opportunities to gain a faster return on their investment (i.e., projects that are closer to market). Program administrators, in this example,

may find it more difficult to attract project proposals that will yield much greater social than private benefits. In contrast, programs that cover all the research costs may attract proposals that closely address societal objectives, but are weaker from a commercialization standpoint. Without making a financial contribution to the project, the companies funded may have less incentive to commercialize the results of the research. This situation may not be bad for programs that are aimed at creating new knowledge, but for programs aimed at stimulating economic growth or improving industrial competitiveness it may mean failure in achieving their mission if results fail to be commercialized in a timely way.

Conclusion

The ATP and its analogues are complex and intricate in their design, and their internal structures and inner workings have not been well understood by outside observers. Accordingly, our understanding of these specific national programs and their comparative similarities and differences has been limited. Without a lexicon with which to analyze and frame our understanding of these programs, our knowledge of such programs will remain superficial and evaluation and comparison of these programs will lack the necessary underpinnings. In an attempt to move the dialogue forward and to promote a more meaningful understanding of these programs, this paper analyzed program anatomy and constructed a vocabulary for understanding program design choices. It identified and discussed a representative sample of important program design features and provided examples of national programs embodying these design choices. This new lexicon and framework of analysis should improve our understanding of how these programs operate, will facilitate comparisons, and may even prove useful in conceptualizing the design of new programs or of fine-tuning and adjusting currently existing programs. This paper has taken the first steps, but further work needs to be done.

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