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ABSTRACT

This paper investigates technology policy for national governments, particularly the importance of education and training and the role of institutions of higher education as components of such policies for the diffusion and absorption of knowledge, as part of an overall strategy for improving the competitive edge of a nation's enterprises. The paper concentrates on key factors for success in building up strategic alliances between institutions and industry. An examination of the relation between technology policy and the innovation process looks at a linear model and an interactive model and elaborates on the changing approach towards these different models. The paper discusses the three phases of the model used in the Netherlands, which begins with a pre-competitive phase involving conceptualization of the business concept, then testing of the business concept, and finally commercial development of the product. A section on education and training in the Netherlands also looks at linear and interactive models for technology diffusion and describes the interactive Dutch approach. A list of seven success factors is offered. Eight references are included. (JB)

TOWARDS A TECHNOLOGY POLICY IMPLICATIONS FOR EDUCATION AND RETRAINING

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Jean Endo
Chair and Editor
Forum Publications
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1. INTRODUCTION

For national government the best way to improve the competitive edge of enterprises is to invest in an efficient technological infrastructure. Many OECD countries reach this conclusion. Innovation is not only determined by the generation of new technologies but also by the diffusion and absorption of knowledge. Education and training thus become key factors in the process of innovation. Therefore also in government technology policies education & training become core-business.
In this paper we will investigate some of these policies, stressing the important role that institutions for higher education can play in national diffusion policies.
This paper will evaluate some results of the technology policies in the Netherlands related to institutions for higher education. Examples of both stimulating the R&D-process and stimulating education and training will be shown. There is a remarkable resemblance between the two. So we can learn from the experiences in both fields.
This paper will concentrate on key-factors for success to build up strategic alliances between institutions and industry (as well as for research and for education). Also conclusions are drawn towards the government role in technology policy. In the end this paper will make an effort to draw up a short-list of key factors for success.

2. TECHNOLOGY POLICY

Government role in technology policy

In a recent article in *Issues in Science and Technology* Lewis M. Branscomb notices a shift in the U.S. government's attitude toward technology policy. The well known restricted and cautious role of the U.S. government, relying on the market forces to stimulate commercial investments in science and technologies, seems to give way to a more active role to enhance the nation's scientific and technological base.
A major new report from the Council on Competitiveness, titled *Gaining New Ground; Technology Priorities For America's Future*, identifies critical generic technologies driving the American economy and explains what government, labour, industry and institutions for higher education must do to strengthen U.S. leadership in them. Many of the issues that are addressed in these U.S. reports can be found in the technology policies of other OECD countries where the same shift in government approach seems to take place.

Transfer of knowledge and human resources

OECD countries reach the conclusion that they have to invest in an efficient technological infrastructure as the best way to improve the competitive edge of their economies. This infrastructure is not only aimed at the generation of new technologies (R&D) but also on the transfer and absorption of new knowledge (education and training). Nowadays these themes are important issues in government 'white papers' on industrial and technological policies.

A crucial link in the diffusion of knowledge is the human factor. In their study *Made in America* (Dertouzos et al. 1989), the leaders of the MIT Commission on Industrial Productivity warn against the underestimation of the importance of human resources becoming a severe obstacle for competitiveness of enterprises in a rapidly changing (technological) environment.
The OECD-report on *New Technologies in the 1990's* (OECD 1988) also argues that technological change amongst others is a social process and that the potential benefits can only be fully exploited if technical change is accompanied by appropriate structural and institutional reforms.
Both reports stress the importance of technology absorption (diffusion) and the role of educational institutions. This provides a challenge for educational institutions into new 'markets' and new ways of cooperation in joint ventures with the private sector. This also calls for swift innovations in public education, a closer linkage between education and labour market and intensive worker retraining programmes as part of a human resources strategy within industry.

On the other hand, many educational institutions are faced with decreasing enrollment in math and sciences, while society as a whole seems to hesitate, now and then, in its attitude toward technological change.
Notall enterprises grasp the meaning of technological competitiveness in a global perspective and the role of human resource management.
A comprehensive national technology policy that is diffusion-oriented should therefore provide instruments to improve the quality of educational institutions, their ability to attract students in science and technology and to improve industry's capacity to enhance their knowledge-base through further education of their work-force.
The Netherlands, being a small but competitive nation with limited resources, are very keen on policies to improve the infrastructure that is necessary for technological development and diffusion, and to raise awareness of industry on the importance of human resource strategies.

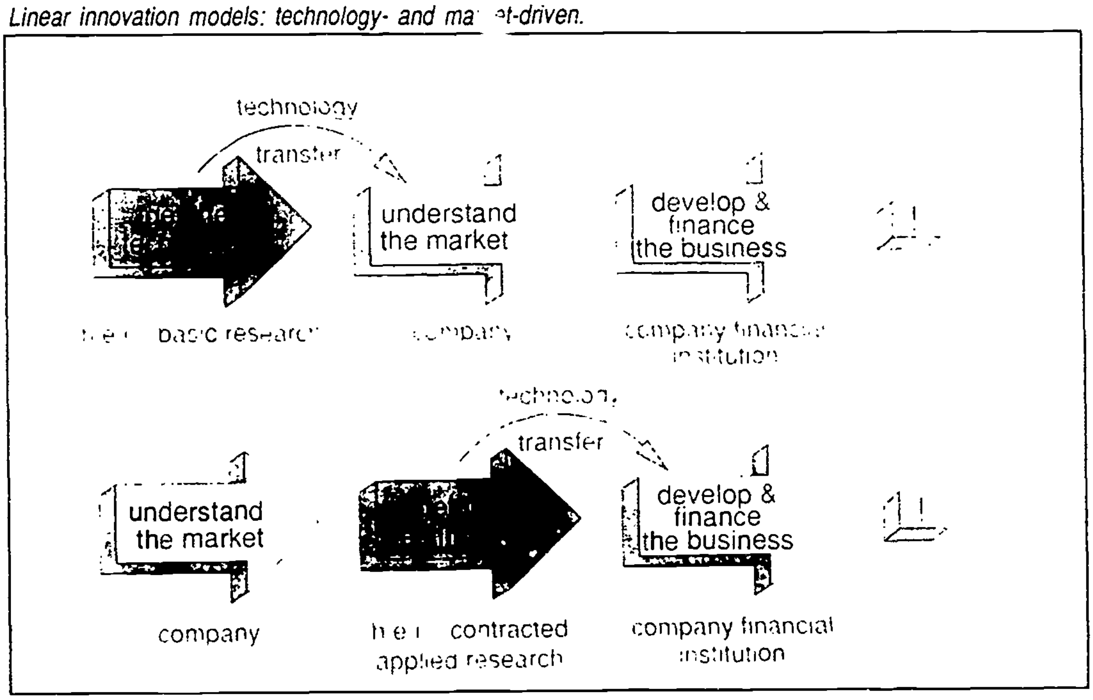
3. TECHNOLOGY POLICY AND THE INNOVATION PROCESS

Technology policy is closely linked to the different phases of the innovation process. There is a changing approach towards innovation that can be summarized as a switch from a linear model towards an integrated or interactive model. Therefore to understand the focus of technology policy this paper will first elaborate on the changing approach towards the different models for innovation.

Linear model

The process of innovation is often conceptualised in two different models that are widely used in both business and higher education. Both are 'linear', and equally flawed models.

1 . Linear innovation models: technology- and ma[illegible]et-driven.



Source: McKinsey & Company

The first linear model is a 'technology-driven' conceptualisation of the innovation process, starting at the 'lab bench' with technological innovations. The knowledge that is thus gained

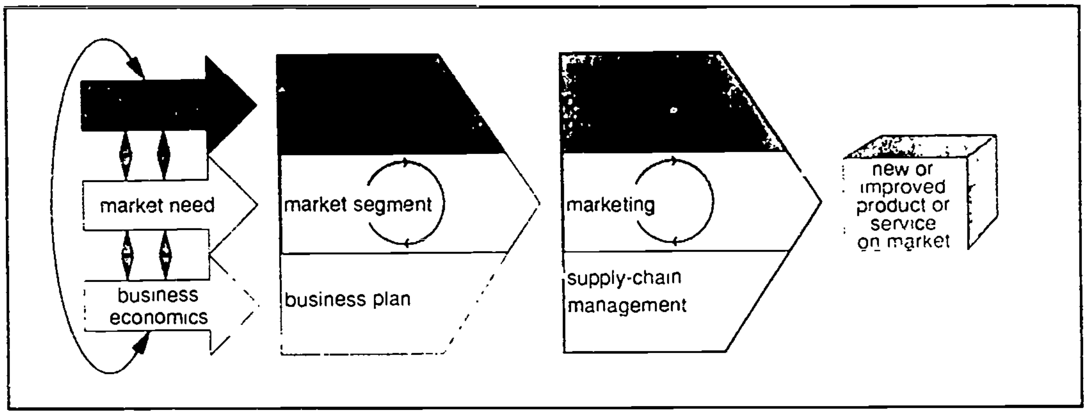
has to be transferred to the development process within a company.
It is clear that this concept is not without flaws: academic innovations may contain valuable technology but they are seldom business concepts ready for development. Companies may exploit the idea without involving or rewarding the institution for higher education. In practice technological and commercial aspects are considered parallel by companies to enable them to be competitive on the market.

The second linear model shows an innovation process that is 'market- driven'. Here we are looking from the other end of the process, the definition of market needs being the starting point. After that a company simply gets the technology needed by contracting a higher education institution.
In this model there is a distinct possibility that the market will have changed by the time the product is exposed to the market. Another risk is that the technology needed appears to be too expensive to commercialise. But even when this model works, the market will only stimulate 'incremental innovation', improving existing products. A customer can hardly be expected to ask for what he does not know is technically feasible.

Interactive model

In a recent publication of McKinsey & Company (1991) for *The Prince of Wales Award for Innovation* (a 'pro-bono' assignment in collaboration with 'Business in the Community') a more interactive model for succesful innovation is developed. This model is a simple framework, based on best practices, emphasising the need for integration of technology, market and economic contributions throughout the innovation process (the model resembles the so-called 'chain-link-model' that Kline & Rosenberg developed in 1986). It is this model that we use to focus on the key factors for success in higher education-business partnerships and on the roles of government, business and institutions for higher education.

2. Interactive innovation model



Source: McKinsey & Company

The first phase of the model conceptualises the generation of the business concept, integrating three different kinds of insights.
- The different technological insights which create the potential for a new product or service. These strategic technologies often originate from different sources - academic and industry - and innovation arises at an interdisciplinary level.
- The insights into market needs, including latent, even unspecified, customer demands.
- The business economic insights which understand how the technology will add real value in a properly funded and profitable business.

The second phase of the model builds on the business concept that emerged from phase 1. In phase 2 this concept is tested and technical and commercial risks are minimised. "This requires further development of the product and process technologies by prototyping, specific market research, and developing a clearer business case. The different people involved in

technology, market analysis and business planning must work together in a focused and structured way. Though shorter and more focused than the first phase, an order of magnitude more resources are typically required" (McKinsey, 1991).

The third phase consists of the commercial development, from production set-up and product-refinement to marketing launch. This demands 'simultaneous innovation': product and process development, marketing and supply chain development.

4. EVALUATION OF THE INTERACTIVE INNOVATION MODEL; LINKS WITH TECHNOLOGY POLICY IN THE NETHERLANDS

First phase

The first phase of the innovation process is pre-competitive. This enables more than one academic research group and also more than one company to join the programme.
Government technology policy is aimed at stimulating this process by bringing together public and private parties. Also by limited funding government technology policy tries to minimise the obstacles of uncertainness that are so typical for this phase: no clear market needs nor clearly emerging technologies.
With the extra funding government participates to these programmes on a joint-venture basis. By partly covering the risk government enables both companies and institutions for higher education to overcome their hesitations for cooperation in an uncertain phase.

3. A Dutch example: the IOP-programme's
IOP stands for Innovative Oriented Research Program. In the 70's the Department of Economic Affairs took initiative to launch the IOP's. IOP's objectives are to stimulate further research on new technologies in research institutes that are well-promising and important to industry in the Netherlands. Within a few years the IOP developed in a joint effort of government, research institutions and industry.
The IOP's have important results. They contribute to a nigh standard of research within institutions, which is partly based on the demands of industry. This enables enterprises to develop new technologies more easily in products that are commercially interesting. In this way also a major contribution is made to the innovation within industry and so to the competitive edge of Dutch economy. Important side-effect of the IOP is a better communication between research institutions and industry. There is a growing network and R&D-cooperation between the two. Also the IOP-programme's force industry to clarify the important issues in research for the next decade or so. In this way research institutions can get their priorities straight, which contributes enormously to the effectiveness and efficiency of the institutions.
Financially IOP's are joint efforts of government and resear institutions on a 50%-base. Government spends approximately $ 20 million a year in these IOP's. Research institutions spend the same amount. In some IOP's industry also contributes financially.

We can also derive from the model that government should focus its technology policies on interdisciplinary centres of excellence where real advances can be made with a fusion of different technologies. When such centres are not only an organisation of academic disciplines but also involve participation of industry, collaboration in more than one phase of the model emerges quite easily.

The roles of the different partners have different perspectives. Higher education institutions and companies are interested in combining their knowledge from their own viewpoints and interests. Government is interested in broadening the national technological basis, and diffusion of technology to industry. According to the McKinsey model, these interests meet when all partners involved combine their efforts in an early stage.

4. A Dutch example: centres of excellence
Recently Dutch government has started a programme to facilitate the foundation of centres of excellence. The programme means to concentrate research activities on one specific field in a limited number of institutions. In this way not only integration of research-programmes is realized but also the institutional integration.

The Department of Economic Affairs contributes an amount of $ 25 million to this programme over a period of four years.
An example in the Netherlands is the Telematics Research Centre in Enschede. This is a joint venture of Philips, IBM, the Dutch Telecom, the departments of Education and Science and Economic Affairs and the University of Twente.

Second phase

In the second phase of the innovation process a company will take the lead, seeking its competitive edge, working together with a specific research group of academics and, most probably, company R&D-personnel.
In this phase the government may lean back: the market-forces are working. Special funding however may be needed for the small and mediumsized enterprises (SME's), that are not able to organise the resources needed. In the Netherlands companies with less than 100 workers are reckoned to belong to the category of the SME's. It is estimated that 95% of the companies in the Netherlands belong to this category. These firms employ some 60% of the national working force.
Government funding should aim to bring together more SME's operating in the same market, enabling them to innovate on a larger scale.

5. A Dutch example: PBTS
PBTS stands for Programmatic Enterprise Orientated Stimulation of Technology. This programme means to stimulate research on the application of new technologies within industry. Companies can apply for financial support (to some 40% of the project's costs) for the introduction of new technologies within their firm.
The yearly budget is $ 70 million. In 1992 approximately a thousand companies have benefited from this programme. In many cases companies use the extra funds to cooperate with institutions for higher education and research institutes.

Third phase

In the third phase there should be (generally spoken) no longer an involvement of government. This is the market-place. However here too SME's reluctantly absorb innovations; they simply lack the capacity. So there can be a selective role for the national government.

6. A Dutch example: KIM
KIM stands for 'Knowledge-carriers' in small and medium sized enterprises. The programme means to stimulate SME's towards innovative activities. Therefore SME's have to employ higher educated workers for development activities in specific projects. Often the employment of this employees is uncommon for SME's ("too smart", "too expensive", "not practical enough", etc.). Dutch government subsidises temporarily a part of the project's costs in a limited number of companies under strict conditions.
KIM is a small kind of experimental programme. The yearly budget is $ 2 million. However the programme is very popular. Some 80 companies make use of the programme and more participants (for example local authorities) want to adopt the programme.

5. TECHNOLOGY DIFFUSION: EDUCATION AND TRAINING AND DUTCH EXAMPLES

Another important aspect of diffusion of knowledge is recognized in the growing importance of education and training. Preparing young individuals for a working future, where rapid technological change will demand constant learning and adaptation of skills, must be followed by regular training efforts in companies. Similar to the R&D-process here we can also see all kinds of cooperation between business and education, developing patterns (networks) for collaboration with long-term mutual benefits. In a way, these processes too could be conceptualised in models of innovation.

Linear model

Within the linear framework we could assume a 'technology-driven' process:
- a company introduces a new technology;
- a lack of adequate qualifications in its work-force is recognized;
- a training programme is developed;
- workers are trained;
- or new personnel is hired, that is already educated with expertise in this particular field of knowledge; consequently the older workers without that knowledge are fired.

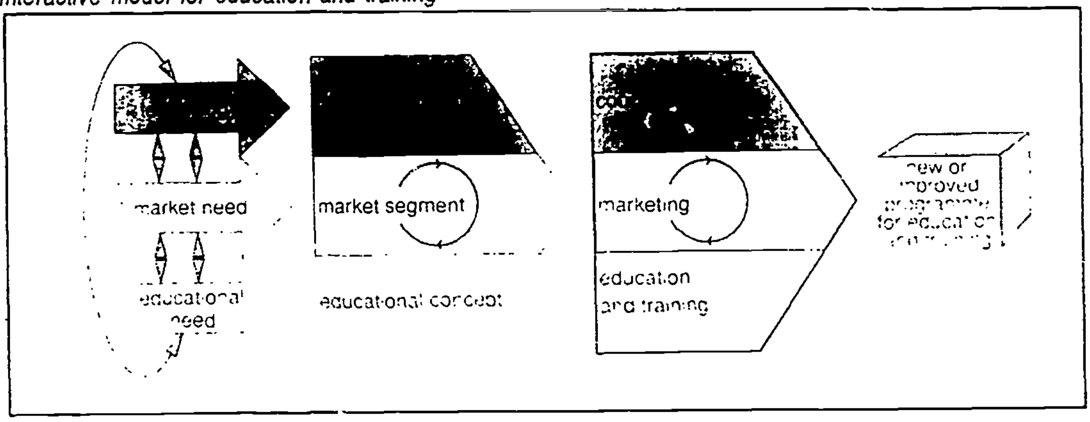
We can easily see where the flaw is: a linear model denies the long leadtime of recognizing the problem ("our workers lack the knowledge to support the company's innovations"), taking action (hiring new personnel or setting up a training programme) to a situation where the workforce can actually work with the new technology.

The same goes for the linear 'market-driven' model: it will take some time and effort before the market (companies in need of specialized personnel) can articulate its needs (both quantitatively and qualitatively) to institutions of higher education as providers of education and training. And after that, the education and training process itself will take quite some time.

Interactive model

We therefore introduce the interactive model of McKinsey & Company for succesful innovation on education and training. Here the framework should integrate technology, market needs and educational expertise.

7. Interactive model for education and training



Analogical to the McKinsey-model on R&D in the first phase the provisional contours of a new education/training-concept are developed. Here too different kinds of insights are integrated:
- The different technological (and other) developments that influence the knowledge base for companies. This implies a thorough strategic survey of technological change, new possibilities for products and services, different ways of delivering services or production, organisational change, etc.
- The translation of this survey into expectations about the kind of knowledge that companies will need to grasp opportunities and fence off threats.
- Insights from education how to change study-programmes for future generations of students or how to plan a training scheme for those already at work.

7. A Dutch example: educational monitor of an industrial sector
In the Netherlands government has recognized the need of both the educational field and industry for better communication. An important element is the articulation of industry's educational and training needs. Therefore recently a project has started to enable industry to monitor crucial developments within several industrial sectors and to translate these developments into educational and training consequences.
In this project industry and education participate both realising the mutual interest of better communication. The department of Economic Affairs took initiative to this project. Support is only temporarily. When there is a fully developed method and a steady practice within an industrial sector, interested parties have to uphold the effort themselves.

In the second phase of the model both education and business are involved in building new curricula, bringing together expert knowledge on specific technologies and the best way to learn them. In this phase a clearer picture of the needs of industry, and the possibilities to fulfil these education and training needs, is developed. Both parties can learn from each other, bring together resources, develop learning materials, courseware, etc.

8. A Dutch example: PRESTO
PRESTO stands for Project Effective Stimulation of Technology in Education. The project is aimed at institutions on vocational education. In 1990 the Department of Education and Sciences took initiative to PRESTO; the Department of Economic Affairs joined the programme. PRESTO means to contribute to innovation in educational institutions. But there are constraints: government only contributes to joint ventures of educational institutions and their environment for instance local companies. In this way co-makership is a condition to the project. This makes a clear ppp. The interest of both educational institution and companies are obvious. The results of PRESTO are several. Educational institutions get access to modern equipment and accurate training programmes. Companies can influence parts of the curriculum and can recruit quite easily well trained young workers. Also there are some important side-effects: schools and companies learn to speak each others language. They learn to find one other. Companies experience that their demands towards education are expensive. So they tend to be more selective in their demands and will see to the fact that demands are only made if strictly necessary.
Financially government contributes some $ 20 million to the project over a period of four years.

In the third phase there is a new curriculum or a training scheme. Now business and education participate in delivering them: business may provide some highly skilled workers as part-time teachers, educational specialists may advise the company on personnel matters concerning the training programme, equipment from both sides is 'pooled', dual learning opportunities may arise (an alternation of learning and working), etc. Government will play no role of importance in this phase, with the earlier mentioned exception for projects regarding SME's.

9. A Dutch example: Regional centres for technology
In the 80's both the ministry of Education and Sciences and the ministry of Economic Affairs were involved in facilitating the founding of regional centres for technology, linked to institutions for vocational education. In these centres the most advanced equipment is available to schools in the region that can send their students to the centre in order to obtain experience in new techniques. The centres are also, that is more and more, used by SME's to train their workers in using the new techniques. After a period of government funding, the centres now have to become self-supporting, for instance by contract-activities.
In the 80's 12 centres were founded, involving government expenditures up to $ 20 million.

6. CONCLUSIONS

In this paper we have argued that investment in an efficient technological infrastructure is important for economies to improve their competitiveness. Within the technological infrastructure not only research and development but also education and training provide important instruments for diffusion and absorption of knowledge and thus for the innovation processes in the economy.

We have also focused more in detail on the innovation processes in R&D and in education and training elaborating on an interactive model for successful innovation. With the help of some Dutch examples concerning interactive innovation strategies, we have gone through the various stages of innovation.

We may conclude that the interactive model implies strongly a long term and close cooperation between business and institutions for higher education. Government can facilitate this cooperation in various ways depending on the particular stage in which the joined efforts of an innovation project are.

From the interactive model for innovation and the examples given, we can derive key-factors for success. These factors must be seen as important conditions for cooperation between business and higher education.

7. SHORT-LIST OF SUCCESS FACTORS

1. Choice of partner

As in real life the choice of a partner is the most important success factor. A partnership has to be based on mutual trust and a strong belief that both partners can contribute to the partnership. Getting acquainted is an important preliminary for intensive collaboration.
A strong, even leading position in a certain discipline or technology is also a comfortable starting point for collaboration.

2. Professionality

In all stages of the interactive innovation process, both business and higher education have to rely on each other's professionality in their respective disciplines. If business should come to an institution for higher education with a ready-made concept ("hey guys, this is how you should do the job") or academics turn their noses up at marketers, cooperation will be extremely difficult. In the interactive model both partners cooperate because of the differences in know-how and approach.

3. Commitment

In the first stage of the innovation process the consequences are incalculable. This implies that on both sides of the partnership top-level-commitment is needed to overcome unforeseen obstacles, to bridge gaps in understanding and funding, etc. Innovation projects should therefore result from clear intentions from both sides, and the commitment can best be formalised (however, simple arrangements can not replace mutual trust).

4. Long term perspective

To our best knowledge and experience there is no 'quick fix' or 'fast buck' in innovation. The model we use, shows a long term process in which both partners need to stick together even when outcomes are still in the lap of the gods. After the first, difficult and often tiresome stage of the innovation process there is yet another stage to go through. This implies that both partners need a longer term perspective to be able to overcome temporary delays and setbacks. This perspective is often a strategic mutual goal: to be number one competitors in a certain field.

5. Exchange of experts

Business and higher education have their own 'corporate' structures and cultures. Longer term, interactive processes can be facilitated by the (temporary) exchange of experts from both sides. This often increases understanding of cultural differences and approaches and facilitates the longer term, mutual, commitment. In effect, the concept of 'learning organisations can benefit from exchange of views and approaches.

6. Clear responsibilities

Especially in a complex and long term process, responsibilities have to be crystal clear for all involved. Nothing is more frustrating in a partnership than a partner who does not come up to expectations. A process-manager with sufficient authority sees to it that everyone does his/her part of the job and meets the deadlines. Top-level management is informed regularly and takes action when necessary. Top-level managers from both parties join periodically to discuss progress.

7. A 'facilitating' environment

We have shown that government (federal, state or local) can facilitate partnerships. Often, government brings together partners that were not aware of each others needs or possibilities. Sometimes co-funding or other incentives can ease the way. Another important aspect may be the long term perspective that government can pursue more easily than institutions or corporations.

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