December/99

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ISSN: 1025-9384

5 EURO ΕΥΡΩ

The IPTS REPORT

EDITED BY THE INSTITUTE FOR PROSPECTIVE TECHNOLOGICAL STUDIES (IPTS)
AND ISSUED IN COOPERATION WITH THE EUROPEAN S&T OBSERVATORY NETWORK

SPECIAL ISSUE: EVALUATION AND RESEARCH ACTIVITIES

EUROPEAN COMMISSION
Joint Research Centre

ENGLISH VERSION

ABOUT THE IPTS REPORT

The IPTS Report was launched in December 1995, on the request and under the auspices of Commissioner Cresson. What seemed like a daunting challenge in late 1995, now appears in retrospect as a crucial galvaniser of the IPTS' energies and skills.

The Report has published articles in numerous areas, maintaining a rough balance between them, and exploiting interdisciplinarity as far as possible. Articles are deemed prospectively relevant if they attempt to explore issues not yet on the policymaker's agenda (but projected to be there sooner or later), or underappreciated aspects of issues already on the policymaker's agenda. The long drafting and redrafting process, based on a series of interactive consultations with outside experts, guarantees quality control.

The clearest indication of the report's success is that it is being read. An initial print run of 2000 for the first issue (00) in December 1995 looked optimistic at the time, but issue 00 has since turned into a collector's item. Total readership rose to around 10,000 in 1997, with readers continuing to be drawn from a variety of backgrounds and regions world-wide, and in 1998 a shift in emphasis towards the electronic version on the Web has begun.

The laurels the publication is reaping are rendering it attractive for authors from outside the Commission. We have already published contributions by authors from such renowned institutions as the Dutch TNO, the German VDI, the Italian ENEA and the US Council of Strategic and International Studies.

Moreover, the IPTS formally collaborates on the production of the IPTS Report with a group of prestigious European institutions, with whom the IPTS has formed the European Science and Technology Observatory (ESTO), an important part of the remit of the IPTS. The IPTS Report is the most visible manifestation of this collaboration.

The Report is produced simultaneously in four languages (English, French, German and Spanish) by the IPTS; to these one could add the Italian translation volunteered by ENEA: yet another sign of the Report's increasing visibility. The fact that it is not only available in several languages, but also largely prepared and produced on the Internet World Wide Web, makes it quite an uncommon undertaking.

We shall continue to endeavour to find the best way of fulfilling the expectations of our quite diverse readership, avoiding oversimplification, as well as encyclopaedic reviews and the inaccessibility of academic journals. The key is to remind ourselves, as well as the readers, that we cannot be all things to all people, that it is important to carve out our niche and continue optimally exploring and exploiting it, hoping to illuminate topics under a new, revealing light for the benefit of the readers, in order to prepare them for managing the challenges ahead.

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PUBLISHED BY THE EUROPEAN COMMISSION
Joint Research Centre
ISSN: 1025-9384
Catalogue Number GK-AA-99-010-EN-C
DEPOT LEGAL: SE-1937-95

PRODUCTION
CINDOC-CSIC/CL SERVICIOS LINGÜÍSTICOS

PRINT
Graesal

TRANSLATION
CINDOC-CSIC/CL SERVICIOS LINGÜÍSTICOS

THE IPTS REPORT
is published in the first week of every month, except for the months of January and August. It is edited in English and is currently available at a price of 50 EURO per year, in four languages: English, French, German and Spanish.

SUBSCRIPTIONS
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EDITORIAL

Isidoros Karatzas and Gilbert Fayl, *Evaluation Unit, DG Research*[1]

The European Commission's experience in the evaluation of RTD programmes covers a period of more than 2 decades. From 1980 to 1994 more than 70 programme evaluations and over 40 supporting studies have been carried out, involving more than 500 European experts. The Commission's efforts, coupled with major evaluation activities in the Member States, have been a catalyst for the establishment of a European evaluation community, where extensive knowledge transfer, sharing of experience and application of good practices is fostered.

The evaluation efforts have had a double focus: to provide managers with a tool for real-time improvement of programme implementation and to provide a performance and impact measurement in order to influence the design of the new activities.

Up until 1994, although it was based on a sound methodology, the interface with policy preparation was not as direct as one would have wished. In 1994, with the introduction of the fourth Framework Programme on RTD activities (FP4), the evaluation system underwent a major overhaul. Firstly, the evaluation efforts were harmonized across all RTD programmes with an increased emphasis on the transparency, democratic accountability and better synchronization of the evaluation and policy functions. Secondly, the evaluation of the impact of research activities became the main focus.

The new scheme introduced a continuous monitoring process, reporting annually, and a five-year assessment carried out halfway through programme implementation, covering two subsequent programmes and reporting in time for the preparation of the new programme. Thus, the five-year assessment combines an ex-post evaluation of the previous programme and a mid-term review of the ongoing one. The backbone of the evaluation process has remained the use of external independent expert panels. Independent expert panels assist in the ongoing monitoring. Separate panels are appointed to conduct the five-year assessments. Both the monitoring and five-year assessment are carried out concurrently for all specific programmes and the results serve as a major input to the Framework Programme level exercises.

With the introduction of the new scheme, the evaluation process became a topic of intense and continuous internal discussions in an effort to address the needs of its primary users, which include the RTD programme managers and the decision-makers in the European Parliament and the Council of Ministers. For this purpose the Interservice Group for Monitoring and 5-Year Assessment was established and is composed of representatives of all Commission's Directorate-Generals (DGs) involved in the implementation of the Framework Programme and also including Budget, Financial Control and Statistics DGs.

In addition, the transparency of the process is enhanced by introducing a formal feedback mechanism requiring the Commission to publish responses to the independent experts' recommendations. Subsequent panels are also requested to enquire whether the recommendations have been implemented. Additional feedback from the decision-makers and the national RTD actors is received primarily through two channels:

- the CREST[2] Evaluation Sub-committee that reviews the evaluation reports and recommends means to improve their effectiveness, and
- the European RTD Evaluation Network[3] which is

a forum for discussion and analysis of evaluation methodology and good practice.

Evaluation is always a tricky process, not least in an area like RTD where the results are, and indeed must be, uncertain. It is hoped, therefore, that this special issue can also be of help in sharing experience and good practice, so that the results of evaluations can be viewed with the maximum confidence. The underlying theme of each article is the maximization of the impact of evaluation work either by targeting the methodology or by responding better to the users needs. The described efforts are complementary to the work undertaken by the Commission in support of the monitoring and 5-year assessment panels. An example of such work is outlined in Box 1 and deals with the definition of the constituting elements of European Added Value.

Box 1. The constituting elements of European Added Value (EAV)

Among the new selection criteria for the Fifth Framework Programme (FP5) is that related to the "European Added-Value" (EAV), a concept derived from the subsidiarity principle, that could be defined as the added value that could not be generated at national or regional level. In more practical terms, EAV relates to scientific and technological objectives to be pursued at European level and involves the development of critical mass, the contribution to the implementation of Community policies and to addressing European problems.

The study envisaged here should look at the questions and issues relating to the identification of the EAV of the EU Research programmes. **Its objective is, on the one hand,** to address the problem from a global perspective by increasing knowledge and understanding of the constituent elements of EAV and their measurability and, **on the other hand** to illustrate by a case study the capacity of European RTD policy to fulfil its purpose regarding general EU socio-economic objectives.

One of the main purposes of the study will then be to provide an operational notion of EAV that could be applied, in different areas of European research, systematically and consistently at the various levels of: policy development, programme definition, project selection, implementation and follow-up.

The need for a better understanding of these questions is moreover increased with the adoption of FP5. Clear orientation towards a socio-economic problem-solving approach has been accepted. The objectives and criteria to be used for projects selection and evaluation have stronger socio-economic components than in the past, which results notably in the need to adapt accordingly the programme's monitoring and assessment. There is therefore a clear need for improved evaluation tools, in order to demonstrate impact, take corrective actions where necessary and improve the design of future programmes. These requirements would be supported by the better understanding of EAV, as perceived by the different actors/stakeholders that the study will provide. Among the principal questions for the study to address are:

A) What are the elements constituting the Framework Programme's EAV? All relevant aspects should be explored here and each element identified shall be illustrated by an example. How can the elements constituting the EAV of the Framework Programme be enumerated and defined in respect of its different components including:

- **Scientific and Technological Excellence:** The importance of critical mass, building of European scientific community, internationalization of science, emphasis on collaborative research, importance of researchers' mobility.

In enumerating the ways in which the FP generates EAV, the study should also describe the factors defining the limits to what it can achieve in each of the above areas (for example, shared responsibility with Member States in the regulatory environment, problems inherent to programme design, misspecification of objectives)

- **Economic benefits:** to what extent has the Framework Programme contributed via innovation to gains in competitiveness and the exploitation of the potential of the Internal Market, generated direct and indirect economic benefits and facilitated the establishment of European norms and standards?
- **Regulatory effects:** to what degree has the Framework Programme contributed to the establishment of the European institutional and regulatory framework?
- **Networking Effects:** How has the Framework Programme contributed to the establishment of networks for the dissemination of S&T knowledge, for example particularly in the area of industry/university collaboration.
- **Social Objectives:** How has the Framework Programme contributed to the achievement of EU social objectives (environment, health, education and training, employment, social and economic cohesion etc.)

B) What is the importance of these constituting elements:

- for all the different stakeholders (projects participants, EU institutions, Member States' government and public administrations, industry, citizens' groups, NGOs)?
- in addressing the socio-economic problems that the FP, as an instrument, is designed to tackle?

C) What are the indicators/methodologies which can be used for their qualitative and whenever possible quantitative measurement?"

D) How should these indicators/methodologies be best used to enhance the assessment of FP4 and FP5 EAV?

The case study concentrate on one of the following socioeconomic themes:

- improving health of European citizens.
- transportation of population (increased mobility) and goods in the European Union

Based on the analysis of the EAV performed in the generic part, the case study will quantify and qualify the added value of the FP (previous FPs and in particular FP3 and FP4) as regards the selected socio-economic themes. The mobility of people and therefore their transportation within the EU constitutes together with the transportation of goods is a very important factor of social and economic development and for the preservation of the environment. It involves a huge variety of actors (regulatory bodies, policy makers, many industrial and service sectors, representatives of citizens and consumers' interest, other NGOs, scientific community, research organization,...). Even more numerous are the actors concerned by the improvement of health standards which certainly is key for all citizens and encompasses problems that can greatly benefit from a pulling of the resources at the European level.

Source: Liam O'Sullivan and Yves Dumont, Evaluation Unit, DG Research.

Notes

1- This work is the product of a team effort by the Evaluation Unit of DG Research, including Liam O'Sullivan, Yves Dumont, Luc Durieux, and Helga Teuber.

2- CREST is a body composed of Member States representatives advising the Commission and the Council of Ministers on S&T issues.

3- The members of the Network are evaluation experts from the national authorities (Ministries, Institutes, Research organizations) from the EU Member States, Norway and Israel.

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Public Research Programmes: Socio-economic Impact Assessment and User Needs

Rémi Barré, *OST and CNAM*

Issue: A major objective of evaluations of recent technology and development programmes is to assess their impact. However, a narrow focus on impact measurement and evaluations creates a risk of losing credibility and relevance for policy-makers.

Relevance: To meet the undeniable need to evaluate the socio-economic impact, evaluation may need to be considered in a broader sense, as a learning process, linking researchers and clients, aimed at building strategic intelligence into the system through experimentation and debate.

Introduction: measuring impacts

The Fifth Framework Programme (FP5) for Research and Technology Development has explicit socio-economic objectives. It aims to create jobs, promote health and quality of life and preserve the environment through a problem-solving approach. Thus FP5 has in some way to be driven by the needs of society. The recent report *"Options and Limits for Assessing the Socio-Economic Impact of European RTD Programmes"* rightly suggests that FP5 should be looked upon as a "social contract" between the research community and European citizens.

Since the role of evaluation is to bring transparency, accountability and legitimacy, it has to reflect the nature of the research policy objectives. In the case of FP5, for which an ambitious set of socio-economic targets have been set, it is clear that the evaluation scope will have to be as broad as the reality of the EU research policy. It will have to address questions about the contribution of research to the socio-economic objectives of European society. In other words, if European RTD policy is to be accountable to European society, the evaluation of FP5 must directly address the question of how to assess its socio-economic impacts (Dumont et al., 1998).

The obvious first step in assessing something is to measure it. Thus, by giving it the task of measuring impacts, the mandate of evaluation has been immediately transformed into one of impact measurement. But do we know how to measure such socio-economic impacts in any reasonable and credible way?

Evaluation is faced here with the daunting task of measuring the wide variety of impacts

The objectives of FP5 demand evaluation be included so as to assess its socio-economic impacts

There is no satisfactory way to measure impacts, in the narrow sense of the word, and evaluations are in danger of losing credibility and relevance for users

Impact measurement entails measuring the difference between what happened after the research was completed and what would have happened had it not been carried out

The non-linear process by which innovations develop makes it technically impossible to obtain an explicit conceptual model of the phenomenon

relevant to the objectives of FP5, be they economic or social, direct or indirect, short term or long term, tangible or related to knowledge and skills effects. In the report mentioned above, the ad-hoc group of experts set up to review the issue suggests a number of techniques, always strongly stressing their limitations, finally stating, with a certain degree of understatement, that impact measurement represents a "new conceptual challenge". This is reflected by the evaluation reports which have tried to address the question of socio-economic assessment, and which have all ended up presenting a solemn disclaimer regarding their ability to deal with this point. There is a broad consensus in the academic community working on these questions that we face here one of the most methodologically intractable areas of evaluation. Thus easy promises necessarily give way to a defensive attitude stressing the lack of relevant data and lamenting the limits of the available methodologies.

We would argue that our knowledge of the relationships between research activities and society is not up to the task of socio-economic impact assessment through some kind of measurement.

A preliminary point is to realize that to measure the impact of research is to measure the difference between what has happened after the research has been done and what would have happened if it had not been done, everything else being equal. This means that to measure an impact, we need to model the system so as to be able to simulate the state of the system if the research in question had not been done, and then to compare it with the actual situation. Our argument is that there are insurmountable technical and epistemological obstacles to ever building such a model.

The technical gap in socio-economic impacts measurement

The first of these obstacles is the technical impossibility of arriving at an explicit conceptual model of innovation. It is widely recognized that innovations do not develop according to a linear model going from basic research to use in society. More appropriate descriptions are the network model, the "chained linked" model or even the turbulence model, —an image highlighting the fundamentally random nature of the process. Furthermore, we also know that the effects of knowledge are largely based on intangibles such as network building, skills and know-how increase impacting on anticipations and strategies. Complex systems of intangibles are hardly appropriate elements for modelling.

In other words, if efficiency is the ratio of outputs to inputs, how do you measure the efficiency of an input when it is one among many which you do not control, and when there are a multitude of non-commensurate outputs, some of which are intangibles? This is the question of attribution (what part of the modification of an output parameter can be attributed to research?) and "additionality" (what difference does it make?). Other aspects are the portfolio effect (the project analysed is to be considered as one in a portfolio), the problems of irreversibility and non-replicability (Guy, 1998, Cameron, 1998). The research - innovation system is no less complex than other well-known complex systems, such as the weather system, in which a proverbial butterfly flapping its wings in one place could trigger a series of events leading to changes in the weather in another part of the world.

The epistemological gap in socio-economic impact measurement

The second obstacle is what we might call an epistemological gap. There is a long chain of events linking analytical knowledge produced by research in the laboratory, to synthetic knowledge (as represented by capabilities and expertise), and finally to decision and action. Obviously, the socio-economic impacts of research derive from action, which means that measuring these impacts demands a model of the whole chain. Moreover, it should be borne in mind that this chain is influenced by the democratic process, and is in no way reducible to mechanistic or stochastic cause-and-effect relationships.

Another way to put it is to observe that the impact measurement approach implies a research mode which is disconnected from the actions and strategies of the actors in the social and economic arenas. It assumes there is some sort of temporal sequence in which research is defined, then done, then its results are injected into "society", which in turn reacts and exhibits "impacts". This model is not only flawed, but, basically, it runs counter to the aims of FP5. FP5, on the contrary, is at the forefront of the "new mode" of research (Gibbons et al., 1996), in which research takes place in a context of application (problem solving), including therefore a variety of actors with differing aims and strategies, but interacting in networks of suppliers and users. In such a context, the research process itself is embedded in society. There is no "impact" of research as such but a multi-actor dynamic involving knowledge creation, circulation and diffusion.

The risk of denying these realities is that evaluation will try futilely to address directly the unrealistic measurement challenge, seeing it as the only legitimate way to approach the impact assessment issue. If such impact measurement *stricto sensu* cannot be done in a meaningful and satisfactory way for technical and epistemological reasons, then all attempts will necessarily fail. As a consequence, the clients of evaluation —decision-makers and stakeholders— will feel they are not being served adequately, and evaluation could lose credibility and relevance. The paradox is that in trying to get closer to its users' interests by promising socio-economic impact measurements, evaluation is in fact placing itself in a position in which it could be creating false expectations and may even end up misleading those very users. The cause of this paradox is that there is a contradiction between the logic of impact measurement and the logic of the new mode of research exemplified by FP5.

How, then, can we reconcile the concept of impact assessment, and the reality of the new mode of research, of which FP5 is paradigmatic? We suggest it can be done by taking the problem the other way around, and first addressing the expectations of the client regarding evaluation in this new mode of research. Only then will we examine the question of handling socio-economic impact assessment.

The basic hypothesis is that evaluation can make sense to users - decision-makers and stakeholders - only if it helps them to play their legitimate role in the knowledge production, circulation and distribution process. In this sense, the fundamental aim of evaluation is to contribute to building a space in the research process for those actors. From this viewpoint, evaluation is one aspect of the research process, of a reflexive nature, having the peculiarity of involving new and different actors, where questions are re-shaped, outcomes linked to new issues and adjustments negotiated. Evaluation retains its classical goals of fostering accountability and legitimization of the research process. It also addresses those accountable for the actions taken and deals with the capacity to adjust the strategy. But in the new mode of research, evaluation is not an external *ex-post* and *ex-cathedra* activity; it is part of the social process of research and innovation. Evaluation, in a sense, consists in

Impact measurement is based on the underlying assumption that there is a temporal sequence in which research is defined, then done, then its results are injected into "society", which in turn reacts and exhibits "impacts"

A re-appraisal of the role of evaluation in the research mode of FP5 is needed in order to reconcile the socio-economic impact issues with policy-makers' expectations

Dealing with impacts in a way that focuses narrowly on measurement implies an understanding of evaluation which is at odds with the new mode of research

In the new mode of research, socio-economic impact assessment is the learning process bringing together a broad set of actors jointly involved in the production - circulation - distribution of knowledge

If research is put forward as the solution to social problems, then it becomes the property of a new set of stakeholders, and the public debates it generates are an important part of its evaluation

building bridges between a broad set of actors, encompassing what is usually labelled science and society (Latour 1999).

Dealing with impacts in a way that focuses narrowly on measurement originates in an understanding of evaluation which is at odds with the new mode of research. To serve adequately the needs of the clients of evaluation, we must consider a different, broader, perspective for evaluation, consistent with the philosophy of FP5.

In this context, the impact measurement mandate is to be rejected. But what does the assessment of socio-economic impacts become? What is its functional equivalent in the evaluation scheme we propose?

What is useful for users and central to the evaluation process is first to make explicit the interactions in the system built by the research project actors. This means identifying, in a qualitative way, the channels through which embodied and disembodied, codified and tacit knowledge circulate from various origins to various destinations. The research activity under examination is here viewed as one of the engines of knowledge creation, combination and distribution in this particular set of actors. We would suggest that one particularly relevant kind of interaction to trace concerns the links between research and policy-making at European or national levels. Such policy-making needs expertise, an adequate basis for regulations, and preparation of collective infrastructure —all of which are aspects which can be traced to research activities. This scheme could also provide a common language for use by researchers, evaluators and policy-makers.

A second task, central to evaluation and to users is related to analytical and descriptive work regarding the programme in question. One important aspect of such analytical work is the process of constructing the indicators, which demands the usually implicit questions regarding the underlying conceptual model of research and innovation be made explicit, together with the relevant classifications or the boundaries of the dynamics to be considered. The other valuable aspect of analytical work is the criticism and debate it arouses. From technical points, one gets quickly to key issues which would have hardly been addressed otherwise. Even if the technical objectives are modest, their potential for collective learning is usually high, since the figures produced can be a useful focus for debate. A wide variety of such analytical work can be undertaken, referring to different methodologies, from surveys to bibliometrics, to economic and statistical analysis, including the gathering of expert opinions in quantifiable form. This task is evidence of the fact that we are not in any sense against quantification. We simply consider it to be a part of a much larger process, and a way of providing new insights and hypotheses rather than single numerical answers.

A third task is directly related to interaction and debate among the actors involved (ETAN Expert Working Group, 1999). If research is put forward as the solution to social problems, then it becomes the property of a new set of stakeholders (Georghiou, 1999) and an important aspect of evaluation is the debates the interested public is likely to have based on its results. The aim here is to understand ways in which actors make sense of their involvement in the projects, as producers or users, and how their capabilities and strategies may be affected now and in the future. This is where the linkage with foresight and technology assessment comes in (See the article by S. Kuhlmann in this issue). Strategic debating, opening up of alternatives, maintaining a diversity of options are the key features of this task. The precautionary principle is also relevant here, since it provides a means whereby untested hypotheses can be fed into the public debate and the process by which action is legitimated. The idea is to build intelligence into the system through experimentation and debate about implications of new knowledge gained through the research activities.

Conclusion

Socio-economic impact assessment consisting of the three above-mentioned tasks, can be best described as a process of learning and experimentation aiming at building the extended networks which constitute the social systems of innovation. In such systems, scientific knowledge does not close the debates, but contributes to it, and, in turn, the debates open new avenues for research itself. Thanks to such socio-economic impact assessment, evaluations can relate scientific activity and the political debate, thus adequately serving its users, be they decision-makers, stakeholders or researchers.

Keywords
programme evaluation, FP5 evaluation, socio-economic impact assessment, new mode of research, policy-maker needs

References

- Cameron, H., *The problem of additionality in the context of RTD programmes,* DG-XII workshop measurement of RTD results/impacts, Brussels, 28-29 May 1998.
- Dumont, Y., Durieux, L., Karatzas, I., O'Sullivan, L., Teuber, H., Fayl, G., *EU RTD Programmes impact - results assessment: a manifold task in a complex system,* DG-XII workshop measurement of RTD results/impacts, Brussels, 28-29 May 1998.
- ETAN Expert Working Group, *Options and Limits for Assessing the Socio-Economic Impact of European RTD Programmes,* EUR 18884, 1999.
- Georghiou, L., *Meta evaluation: evaluation of evaluations,* Special Issue on Proceedings of the Conference Science and the Academic System in Transition - an International Expert Meeting on Evaluation - Vienna, July 3-5, 1998, Scientometrics, 45, *p.* 523-530, 1999.
- Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., Trow, M., *The new production of knowledge,* Sage publications, London, 1995.
- Guy, K., *Conceptual issues in RTD impact assessment,* DG-XII workshop measurement of RTD results/impacts, Brussels, 28-29 May 1998.
- Latour, B., *Politiques de la nature - Comment faire entrer les sciences en démocratie,* La Découverte, Paris, 1999.

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Additionality of Publicly-Funded RTD Programmes

Terttu Luukkonen, *VTT Group for Technology Studies*

Issue: In recent years, the concept of additionality has provided a general framework for evaluating the role of publicly funded programmes in advancing the technological capabilities and options of firms. However, this concept is based on simplified assumptions about the role of public programmes and it is not sufficient to reveal the usefulness of public technology support.

Relevance: The question of "additionality" is related to the basic rationale for public intervention in the technological development of companies. It is relevant for understanding both the potential and the limitations of public action. Since the concept is an important evaluation tool, a reassessment of current assumptions underlying it will help improve evaluation practices.

Additionality means the difference which government-sponsored programmes have made to the recipients, particularly companies, in terms of R&D activities

Introduction

In recent years, both at the national and European level, additionality has provided an important concept for evaluating the role of publicly funded RTD programmes in advancing the technological capabilities of firms. In short, additionality means the difference which government-sponsored programmes have made to the recipients, particularly companies, in terms of R&D activities. This concept evolved into an evaluation framework in the UK in the early 80s, where it was originally used as a justification for public support to technology development in companies. With the help of the concept of additionality, it could be claimed that public funds did not directly substitute for corporate investment in R&D, but were somehow additional to that which would have happened anyway (Buisseret et al., 1995). The UK Alvey programme evaluation (1984-1990), which developed and refined many evaluation tools used later on in evaluation in other countries and at the EU level, used the additionality approach (Quintas & Guy, 1995). The concept was further elaborated within the EC MONITOR-SPEAR programme studies in the late 80s (Georghiou, 1994).

The current use of additionality in evaluation does not adequately assess the role of public programmes in advancing the technological options of firms. If applied rigorously, it may lead to short-termism in policies. This article will explore several types of situations in which public funding is supposed to have failed. Attention has previously been drawn to public funding substituting corporate investment in R&D and to trivial R&D carried out for the sake of availability of public funding. I will present a typology of situations for public support, supposedly successful and unsuccessful, and discuss the relevance of the concept of additionality in this context. In order to illustrate the discussion, I will draw on three studies of Finnish firms in EU framework programmes (Luukkonen and Niskanen, 1998; Luukkonen, 1999; and an unpublished study of Finnish participation in the Fourth Framework Programme).

The concept of additionality

The concept of additionality rests originally on the neo-classical market failure rationale, i.e. the notion that, left to themselves, firms will under-invest in innovative activities because of their inability to appropriate all the benefits arising from them (Nelson 1959, Arrow 1962, Dasgupta and David 1994). Additionality is expected to gauge the difference between the presumed under-investment in RTD by firms and the actual joint investment by firms and public agencies in RTD prompted by the public programmes. With regard to collaborative R&D programmes, of which the EU framework programmes are a prime example, market failure does not relate to the production of R&D *per se*, but to the transfer and flow of information between firms or firms and public-sector research institutes. The costs of transferring and exploiting scientific and technological knowledge are so high that they affect the success or failure with which such knowledge can be utilized (Mowery 1983; Mowery 1994). This will make it necessary to launch policy initiatives which involve more than simply subsidizing the creation of scientific/technological knowledge, especially promoting the transfer of knowledge through networking and collaborative R&D programmes.

In evaluation, the additionality criteria would apply, in principle, to all possible impacts of a government initiative with subsequent difficulties in measurement, for instance, the attribution of effects of a funding which has a short duration (Buisseret et al., 1995). In evaluation practice, however, additionality has become one dimension among many others, such as impact, effectiveness and efficiency (Guy and Arnold, 1993). This blurs the fact that, basically, all the various effects of an initiative constitute the "additional" gains it has brought about.

Government failures

In the economic literature, attention has been drawn to the desirability of avoiding a *substitution* of corporate investments in R&D by public money (e.g. Metcalfe 1995). Some attention has also been paid to another potential problem, that of *trivial* R&D. For example, Quintas and Guy (1995) identified the possibility of trivial collaboration in the evaluation of the large UK "Alvey" programme: the "additionality" criterion which was built-in to the Alvey programme suggests "that Alvey R&D was non-essential for firms' overall business and technology strategies; otherwise they would fund the R&D themselves" (p. 331). Examples are also cited showing that public authorities may, in the case of international programmes such as EU framework programmes, press companies to participate - in order to get a "juste retour" (Luukkonen, 1999). The lever may be the possibility of obtaining national public funds in the future. This will easily lead to participation, which is trivial from the company's point of view. The possibility of substitution and trivial R&D highlight the fact that there may be governmental failures in the launching and implementation of public R&D programmes.

The following section will illustrate these possibilities by examining different combinations of additionality and strategic value of R&D carried out with public support. The discussion considers the viewpoint of the company obtaining public

The concept of additionality rests originally on the neo-classical market failure rationale, i.e. the notion that, left to themselves, firms will under-invest in innovative activities because of their inability to appropriate all the benefits

In the case of collaborative R&D programmes, it is not a question of market failure per se, but in the flows of information between firms or firms and the public sector

Table 1. Additionality vs. strategic value

Strategic value	Additionality	
	High	Low
High	Ideal	Substitution
Low	Trivial	Marginal

support, since it is the only systematic information available and is usually used in evaluation. Still, it is important to recognize that public programmes are launched after a judgement by the public decision-makers of the strategic economic or social value of a given technology area for future options.

If a company has "strategic blind spots", i.e. it fails to foresee important potential future needs and opportunities, R&D related to such options would appear as trivial R&D from the viewpoint of the company

For illustrative purposes, the two dimensions to be considered, strategic value and degree of additionality, have been dichotomized. A cross-tabulation of additionality and strategic importance leads to the following fourfold table (Table 1), in which I have classified the different categories according to their policy expectations:

"Substitution" (category 2) is defined as strategically important R&D which the firm would have done in any case, but when government money was available, it utilized it. Category 3, "trivial" R&D, is defined as non-essential R&D which companies would not have done if government funding had not been available, as referred to above (Quintas and Guy, 1995).

By contrast, the first category, termed "ideal", is strategically important R&D which would not have been carried out without government funding for various reasons (uncertainty, risks, expenses, insufficient appropriability etc.). In an ideal case, a government programme has high additionality in advancing strategically important endeavours. If a company has "strategic blind spots", i.e. it fails to foresee important potential future needs and opportunities, R&D related to such options would represent trivial R&D from the viewpoint of the company. From a well-informed policy-makers' viewpoint, it would represent strategically important R&D. In reality, however, bounded rationality hampers the decision-making of both companies and public agencies.

Category 4 denotes "marginal" R&D, non-essential, unimportant R&D which would have been carried out anyway, perhaps to search for new potential avenues for technology development. It is conceivable that it is exploratory research that a company, with EU funds and an EU consortium available, was able to carry out within a broader network and with broader expertise.

Empirical cases

The above classification was applied to data from an exploratory study of the strategies of *large* Finnish firms and their EU RTD collaboration at the outset of the Fourth Framework Programme (Luukkonen, 1999). Some preliminary findings from a similar, ongoing study at the outset of the Fifth Framework Programme are also used. The paper also draws on unpublished survey data on Finnish firms in the Fourth Framework Programme.

In Table 2, the EU RTD collaboration strategies of the interviewed set of companies have been classified using the categories in Table 1.

The first important observation is that the ideal category contains fewer cases than expected. This is because, especially for large firms, publicly-funded collaborative RTD programmes are most appropriate for the funding of longer-term and exploratory research tasks which benefit from the

Table 2. Companies in different industries and additionality of EU projects

Strategic value	Additionality	
	High	Low
High	**Ideal** Telecommunications projects; a machinery company and a few other projects	**Substitution** Telecommunications projects
Low	**Trivial** Pharmaceuticals, forestry, metals and machinery companies; some telecommunications projects	**Marginal** Early participation

expertise of a larger group. Firms are normally reluctant to bring their strategically important projects to collaborative consortia, in which they cannot fully control the flow of information (Luukkonen, 1999). They wish to fund their strategic projects themselves.

There are, however, exceptions. As Table 2 indicates, these exceptions are particularly from the area of telecommunications (Luukkonen, 1999). In this field, European companies that are each others' direct competitors have come together in their joint interest to develop standards, hopefully to be adopted worldwide. In the telecommunications business, competition is extremely tough, and in some areas, this has been translated into competition between different standards. EU programmes have enabled background research into the creation of new standards and provided forums for creating joint European views. Some of the projects funded represent "ideal" cases in Table 1 and 2, others represent "substitution" cases. Besides formal standardisation organizations such as the European ETSI (The European Telecommunications Standards Institute), new informal forums have emerged for negotiations about standards. European projects have provided such ad hoc forums. Since many EU projects in this field have provided additional negotiation forums, in Table 2, a majority of telecommunications projects have been classified as "substitution". Still, the classification as "substitution" does not fully reveal the usefulness of such projects. European projects have enabled background research drawing on much broader expertise than would otherwise have been possible. EU funding has also given such projects political credibility and support and thus helped European firms in their global negotiations.

Telecommunications firms also had projects in the "trivial" category. This is the category with most cases in various industries. As mentioned above, publicly funded collaborative RTD programmes seem best suited to longer-term and uncertain projects providing the firms with a broader knowledge base and thus expanding the depth and often the speed of the project. Such projects are not yet classified as strategically important, since their outcomes are uncertain. Thus projects termed trivial may turn out to be far from trivial, especially if looked at in the longer-term. We need to make a distinction between "truly trivial" cases, referred to above, and those that seem to be trivial for their long-term and uncertain nature.

The "marginal" category is interesting. Very few interviewed technology and R&D directors of companies reported participation which could be classified as "marginal". By contrast, according to a survey with participants in the fourth framework programme, research scientists reported fairly large groups of "marginal" cases (24 % in SMEs and 39%

In some areas, particularly telecommunications, EU programmes have brought competitors together and enabled work towards common standards

Participant companies regarded EU programmes as useful and strategically important because they provided intangible goods such as a forum for standards discussions among European competitors

in large companies; unpublished data). The difference may result partly from the different perspectives of senior management and research personnel, with the former group emphasizing greater selection in the company's RTD projects in general and consequent greater importance of all projects.

The description above is based on data from large companies. The situation is somewhat different for SMEs. Available survey data indicate that for SMEs, EU RTD programmes play an "ideal" role more often than for large companies. SMEs cannot usually afford long-term R&D, and their EU projects are often shorter-term, and of greater strategic importance (Luukkonen, 1999).

Discussion

As to the interpretation of the typology of public support, presented above, it is true for the sample examined that the telecommunications firms in many cases replaced private money with public money to carry out R&D activities they would have done anyway. However, these companies regarded EU programmes as useful and strategically important because they provided intangible goods: they provided an additional forum for standards discussions among European competitors and facilitated contacts. European firms have been successful in worldwide competition over telecommunications standards. This cannot be regarded as a result of EU collaboration, though the latter has been a facilitator especially since EU collaboration has been perceived to provide political support to the technical solutions recommended. Thus EU collaboration played an important role in the development of the third generation of mobile phone communication standards.

With regard to the industries that participated in "trivial" projects, their unimportance was partly related to their long-term nature. These also involved new complementary technologies and new partner links that had previously been quite weak. There was considerable uncertainty as to the outcome, especially as to the commercial importance of the projects. Such "trivial" projects may in the end turn out to be strategically important. The trivial class also included projects which were capability building and furthered general knowledge acquisition. However, it is to be remembered that there may also be "truly" trivial projects, as referred to above.

The "marginal" category in the survey data is more difficult to interpret. Companies carried out R&D activities that they might have undertaken anyway, and not only in their core areas. It may be a question of long-term R&D activity, the value of which is still uncertain, but which the company undertakes with public money, since it is available.

The above findings highlight that a simple concept like additionality and particularly its routine application in surveys, is not sufficient to reveal the usefulness of public technology support. The examples of the "trivial" and "substitution" categories highlight this aspect. At first sight, even they appeared to be unwanted cases of public support, but especially the so-called "trivial" category cases may turn out to be successful in the long run. These are often capability building projects, which may open up potential new areas of economic exploitation in the future. The "ideal" case of support, that of high additionality and high strategic value, may be ideal when considered in the short-term since it is based on the present-day assessment of what is strategically important. Public technology support may have most potential in promoting longer-term activities and longer-term additionality, which is difficult to evaluate in the present day. If we put too much emphasis on additionality termed "ideal", as defined above, we end up with short-termism in our policies. Because of the long-term nature of technology development, its impact is inherently uncertain and we are left with uncertain conclusions as to its value (see Metcalfe, 1995). We may evaluate the successes and failures of policies only in the very long-term, maybe 10-15 years after their implementation. This is awkward for policy-makers who are called upon to prove the appropriateness and efficiency of their policies today. The lesson of the foregoing discussion is also that, in the evaluation of EU projects, we need to use different methods and sources of data. Routine surveys do not reveal the full importance of EU collaboration.

Keywords
additionality in evaluation, EU framework programmes, R&D

References

- Arrow, K.J., *Economic Welfare and the Allocation of Resources for Inventions*, in: R.R. Nelson (Ed.), *The Rate and Direction of Inventive Activity: Economic and Social Factor.* Princeton University Press, Princeton, NJ, 1962.
- Buisseret, T.J., Cameron, H. M., Georghiou, L., *What Difference Does It Make? Additionality in the Public Support of R&D in Large Firms*, International Journal of Technology Management, Vol. 10 (4/5/6), *p.* 587-600, 1995.
- Dasgupta, P., and David, P. A., *Toward a New Economics of Science*, Research Policy, Vol. 23, *p.* 487-521, 1994.
- Georghiou, L., *Impact of the Framework Programme on European Industry.* EUR 15907 EN, Office for Official Publications of the European Communities, Luxembourg, 1994.
- Guy, K., and Arnold, E., *UK Government Practice in Science and Technology Evaluation.* Appendix prepared for publication in the German Metaevaluation Report, ISI, 1993 (mimeo).
- Luukkonen, T., *Additionality of EU Framework Programmes.* Research Policy Vol. 28, 1999 (in press).
- Luukkonen, T., and Niskanen, P., *Learning Through Collaboration - Finnish Participation in EU Framework Programmes.* VTT, Group for Technology Studies, Espoo, 1998.
- Metcalfe, J.S., *The Economic Foundations of Technology Policy: Equilibrium and Evolutionary Perspectives.* In: Handbook of the Economics of Innovation and Technological Change, ed by P. Stoneman. Blackwell, Oxford, *p.* 409-512, 1995.
- Mowery, D.C., *Economic Theory and Government Technology Policy.* Policy Sciences, Vol. 16, *p.* 27-43, 1983.
- Mowery, D.C., *Science and Technology Policy in Interdependent Economies.* Kluwer Academic Publishers, Boston, Dordrecht, London, 1994.
- Nelson, R.R., *The Simple Economics of Basic Scientific Research.* Journal of Political Economy, Vol 67, 1959.
- Quintas, P., and Guy, K., *Pre-competitive R & D and the Firm.* Research Policy, Vol. 24, *p.* 325-348, 1995.

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Distributed Intelligence: Combining Evaluation, Foresight and Technology Assessment

Stefan Kuhlmann, *ISI*

Issue: Evaluation, together with foresight and technology assessment, can be used with different combinations to enhance strategic inputs to policymaking. These combinations can help provide input to European policymaking through a flexible "bottom-up" architecture linking multiple sources of RTD-related expertise.

Relevance: If the data and information resulting from the evaluation of public policies and programmes are used as an input to the planning of future policy initiatives – and not only as an ex post legitimization – *then evaluation might function as an "intelligence tool"*. Furthermore, if evaluation efforts, are also combined with other intelligence tools like science and technology foresight or technology assessment initiatives, a *"tool box" of strategic intelligence* for policymaking could even emerge.

Over the past decade, the issue focus of evaluation has broadened and evolved towards a more all-embracing concern with additional issues and more formative approaches. Consequently, evaluations are being linked more with strategy

Introduction

There have been many changes and developments in the theory and practice of the evaluation of public Research, Technology, Development and Innovation (RTDI) policies over the past decade. In particular, in countries where evaluation has taken root fairly early, the following *trends* can be observed:

- the major rationale for evaluations has shifted and evolved from a desire to *legitimate past actions* and demonstrate accountability, to the need to improve understanding and *inform future actions;*

- correspondingly, the issue focus of evaluations has broadened away from a narrow focus on quality, economy, efficiency and effectiveness, and towards *a more all-embracing concern* with additional issues, such as the appropriateness of past actions and a concern with performance improvement and strategy development;

- approaches to evaluation have evolved away from a purist model of "objective neutrality", characterized by independent evaluators producing evaluation outputs containing evidence and argument but no recommendations; to more formative approaches in which evaluators act as process consultants in learning exercises *involving all relevant stakeholders,* providing advice and recommendations as well as independent analysis;

- this has led to more *flexible and experimental approaches* to the construction of policy portfolios, and to even greater demands for well specified systems of monitoring, evaluation and benchmarking to aid analyses and feedback into strategy development.

Many evaluations thus reflect an increasing concern with the link between evaluation and strategy, with an eclectic mix of methodologies used in the context of individual exercises to satisfy the demands for understanding and advice. Increasing attention is also being paid in many institutional settings to the way in which *evaluation (EV) can inform strategy* – and quite often *in combination with technology foresight (TF) or technology assessment (TA).*

The Need for Improved Strategic Intelligence

Analysts in the field of RTDI policies have abandoned simplistic models of how innovation and innovation processes work. It is increasingly recognized that the dynamics of "innovation systems" –linking industries, research and education organizations, political institutions– are complex and difficult to understand, and that scientific and technological communities, not to mention the "users" of their products, face a number of challenges: (1) *The nature of technological innovation processes is changing.* The manufacture of highly sophisticated products makes increased demands on the science base, necessitating interdisciplinary research and the fusion of heterogeneous technological trajectories. New patterns of communication and interaction are emerging which researchers, innovators and policy-makers have to recognize and comprehend. (2) European policy-makers have to coordinate their interventions with an *increasing number of actors* (e.g. European authorities; numerous national government departments and regional agencies; industrial enterprises and associations; trade unions and organized social movements etc.). (3) The growing cost of science and innovation is also likely to accelerate the *international division of labour in the European research system,* a development which will increase the need for a highly strategic, though not necessarily a centralized, European RTDI policy.

Policy-formulation in these circumstances is not straightforward. There is increasing pressure on policy-makers to:

- *increase efficiency and effectiveness* in the governance of science and technology;
- *make difficult choices* in the allocation of scarce resources for the funding of science and technology;
- help preside over the establishment of an *international division of labour in science and technology* acceptable to all actors involved;
- integrate "classical" RTDI policy initiatives with *broader socio-economic targets,* such as reducing unemployment, fostering the social inclusion of less favoured societal groups and regions, as claimed in particular by the 5th Framework Programme of the European Commission;
- acknowledge, comprehend and master the *increasing complexity* of innovation systems (more actors, more aspects, more levels etc.);
- adapt to *changes in the focus of RTDI policies* between international (growing), national (declining) and regional (growing) levels.

Over the last two decades, considerable efforts have been made to improve inputs into the design of effective science, technology and innovation policies. In particular, formalized methodologies have been introduced and developed which attempt to analyse past behaviour (EV), review technological options for the future (TF), and assess the implications of adopting particular options (TA). As a complement of EV, TF and TA, other intelligence tools such as comparative studies of the national, regional or sectoral "technological competitiveness", benchmarking methodologies etc. were also developed and used.

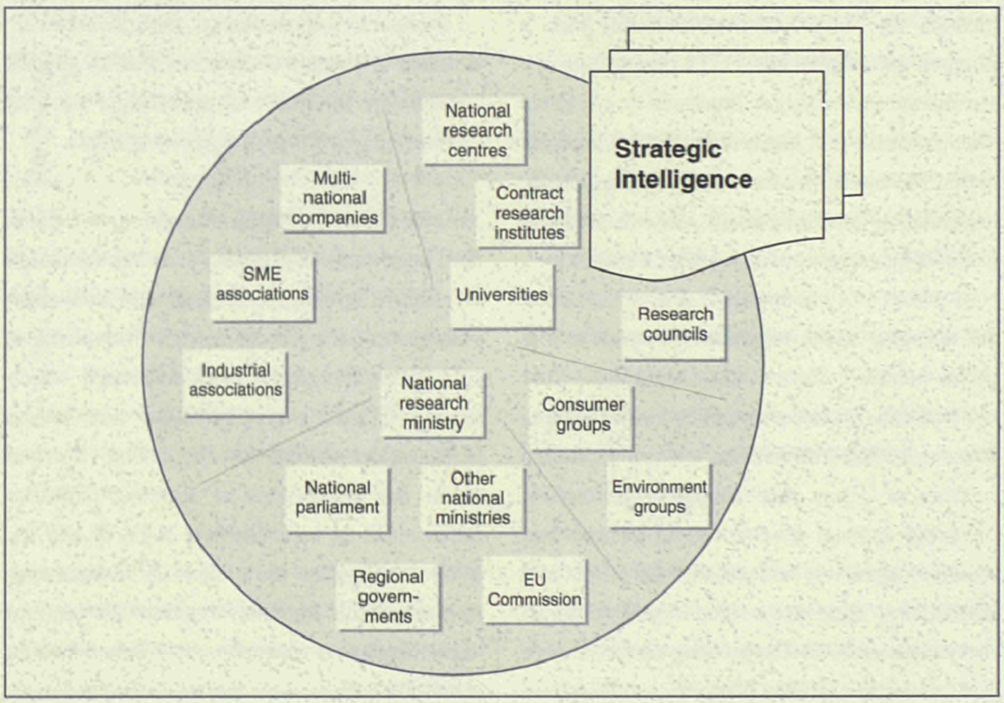
The changing nature of technology, new patterns of communication and interaction and an increasing number of actors have provoked the need for a highly strategic, European RTDI policy

Over the last two decades new technologies have been introduced and policy-makers at all levels have benefited from a greater involvement in the processes of Strategic Intelligence

Policy-makers at regional, national and international levels have all benefited from involvement in these processes and exploited their results in the formulation of new policies. Analytically, one can identify a couple of structural *factors boosting the function of Strategic Intelligence (SI)*:

- a linear model of policymaking as a consequential process (in which the typical steps are: formulation, agenda setting, decisions, implementation, evaluation, formulation etc.) is no longer appropriate, at least not in the field of innovation policies. Here, all typical *steps are more or less interacting*. The emergence of SI knowledge as a policy resource on the one hand, and structural and institutional preconditions of using intelligence activities on the other, influence and transform each other. Often, it is external pressure on policy actors and the related arenas that create the impulse for the production and application of advanced SI;
- RDTI policy is rather (and increasingly) a matter of networking between heterogeneous (organized) actors instead of top-down decision-making and implementation. Policy decisions frequently are negotiated in *multi-level/multi-actor arenas* and related actor networks. Negotiating actors pursue different - partly contradicting - interests, represent *different stakeholders perspectives*, construct different perceptions of "reality", refer to diverging institutional "frames" (see figure 1). "Successful" policymaking normally means compromising through *alignment* and "re-framing" of stakeholders' perspectives;
- contesting and negotiating actors use money, power and information as their main media. Various actors have different shares of these resources at their disposal. *Strategic Intelligence* tools (as EV, TF, TA) use in particular *"information" and knowledge as negotiation medium,* facilitating a more "objective" formulation of

Figure 1. Actors in RTDI Policy Arenas and Strategic Intelligence



diverging perceptions of (even contentious) subjects, offering appropriate indicators and information-processing mechanisms.

Increasingly, it has become obvious to both policy-makers and the analysts involved in the development and use of SI tools that there is scope for continuous improvement and a further need to exploit potential synergies.

RTDI Policy Evaluation, Technology Foresight, Technology Assessment

One can describe the basic concepts of EV, TF, and TA in the following way:

- Practices of science, technology and innovation policy evaluation are wide-ranging, and their functions vary significantly (1) from legitimizing for distribution of public money and the demonstrating the adequate and effective use of the funding by measuring the scientific/ technological quality or the (potential) socio-economic impacts, via (2) improved management and "fine tuning" of S&T policy programmes, to (3) an attempt to improve transparency in the rules of the game and the profusion of research funding enhancing the information basis for shaping innovation policies, in the sense of a government-led "mediation" between diverging and competing interests of various players within the innovation system (Kuhlmann, 1997).

- "Technology foresight is the systematic attempt to look into the longer-term future of science, technology, the economy and society, with the aim of identifying the areas of strategic research and the emerging of generic technologies likely to yield the greatest economic and social benefits" (Martin, 1995)[1].

- Technology assessment: In very general terms, TA can be described as the anticipation of impacts and feedback in order to reduce the human and social costs of learning how to handle technology in society by trial and error. Behind this definition, a broad array of national traditions in TA is hidden (Schot, 1997, Loveridge, 1996).

General Requirements for Distributed Intelligence

A survey of existing practices and experiences with the integrated use of the three intelligence tools for innovation policymaking EV, TF, and TA in various European countries and the EU Commission reveals that there is no "blueprint" of how the tools can be best combined (Airaghi, 1997; Guy, 1998; Fayl, 1997). The configuration should be considered from case to case, depending on the objectives and scope of the policy decision-making process in question. We do not advocate integration per se, but an integration for those cases where a combination of information looking back in time, looking at current strengths and weaknesses, looking at a wide set of stakeholders and at future developments can improve the insights needed to choose between strategic options.

In general, we could state that the greater the potential socio-economic impact of technology and innovation, the stronger the case is for using the full array of available techniques for strategic intelligence.

A number of general principles of Distributed Intelligence for complex innovation systems can be put forward:

- organize mediation processes and "discourses" between contesting actors in related policy arena;
- inject policy in such discourses on the results of EV, TF, and TA, and also analyses of changing

The basic concepts of the new methodologies, EV, TF and TA, correspond to policy evaluation, technology foresight and technology assessment

The greater the potential socio-economic impact of technology and innovation, the stronger the case is for using the full array of available techniques for strategic intelligence

An important precondition of useful Strategic and Distributed Intelligence is the quality and reliability of the information provided

Due to the lack of linkages between individual exercises this has led to the underutilization of existing information, knowledge and capabilities in the process of innovation policy formulation

Better coordination, cooperation, task assignment and development of expertise of national institutions are requisites to guarantee an overall improvement in the functions of DI for RTDI policy

innovation processes, the dynamics of changing research systems, changing functions of public policies;

- there by realize the multiplicity of actor's values and interests;
- facilitate a more "objective" formulation of diverging perceptions by offering appropriate indicators, analyses and information-processing mechanisms;
- create forums for interaction, negotiation and the preparation of decisions;
- respond to the political quest for democracy vis-à-vis technological choices.

Since RTDI policymaking occurs in multiple policy arenas on regional, national, European levels there is a need for "interfaces", linking different systems and related-policy arenas. Some general requirements of Improved *Strategic Intelligence Infrastructures* based on Distributed Intelligence (see Figure 2) are as follows:

- the creation of an architecture of "infra-structures" for Distributed Intelligence – but not one unique "system" – by the linking of existing regional, national, sectoral, etc. SI facilities, horizontally and vertically;
- the establishment of brokering "nodes" managing and maintaining the infrastructure, offering an "enabling structure" allowing free access to all SI exercises undertaken under public auspices, and providing a "directory" facilitating direct connections between relevant actors;
- the guarantee of robustness, including adequate resources.

An important precondition of useful Strategic and Distributed Intelligence is the quality and reliability of the information provided. General requirements for related *quality assurance* mechanisms are:

- the facilitation of repeated and "fresh" exercises (e.g. EV, TF, TA) and new combinations of actors and levels;
- the enhancement and stabilization of professional quality of distributed SI production, including registration and accreditation of professional practitioners, and mechanisms to stimulate renewal.

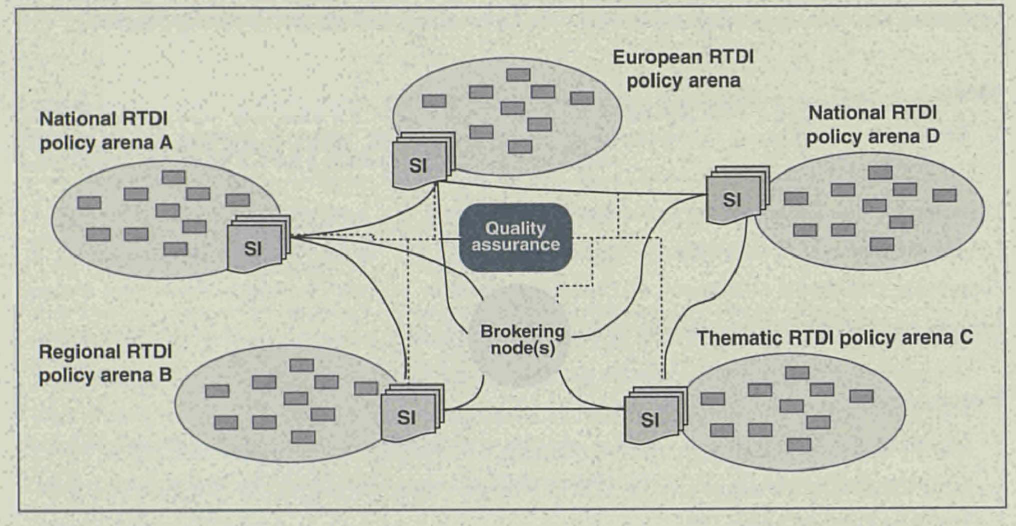
Enhancing Distributed Intelligence for RTDI Policymaking on the European level

Current practices in most countries as well as at the EU level, however, have evolved in an uneven and independent fashion. Individual exercises have rarely been inter-linked either conceptually or politically. This lack of linkages has led to the underutilization of existing information, knowledge and capabilities in the process of innovation policy formulation. Consequently, this has become a major obstacle to attempts at coordinated policy design and practices. For instance, the task set up in the Maastricht Treaty to arrive at a coordinated European science, research and technology policy (including regional, national, and European levels) so far has not been fed by the systematic use of intelligence tools.

In the future, European RTDI policies might put an increased emphasis on mission-orientation towards societal problems (while most diffusion-oriented programmes would remain in the domain of the member states), a tendency that has already been emerging with the FP5. In the longer run, new initiatives, based on comprehensive considerations of needs and opportunities as well as impacts, could be launched to complement current generic programmes and other schemes. This would entail more horizontal activities, and hence different forms of organization of these activities - e.g. using the model of "task forces".

Given the set of existing institutions carrying out the functions of Distributed Intelligence for

Figure 2. Architecture of Distributed Strategic Intelligence (SI)



innovation policy, there is room for considerable improvement in their functioning along the following principles:

- better co-ordination of EV with TF and TA along the policy cycle within the Commission; the already implemented and quite ambitious "impact assessment" procedures provide a useful starting base. Furthermore, the role of the Research DG as a mediator between other parts of the Commission and national innovation policy actors could be strengthened;

- better co-operation between the Commission and the European Parliament in general and in TA in particular. A stronger role for the Parliament, especially with regard to TA;

- better assignment of tasks of the respective institutions, with the focus of EU institutions on information gathering, synthesising and preparation of policy decisions rather than carrying out the research tasks themselves;

- the development and full use of the expertise of national institutions through commissioning, joint projects etc. is a necessary basis for any EU exercise in EV, TF and TA. Information exchange and regular mutual staff exchange between the different communities could be organized on the European level (e.g. in the form of (bi-) annual conferences like those recently organized by the Commission in the context of the European RTD Evaluation Network);

- the development of interfaces between science and technology actors and the general public (e.g. as the Internet-based "Futur-Prozess", recently launched in Germany extending the Foresight experiences of the 1990s).

In such a world of distributed policy-making, a Strategic Intelligence architecture would facilitate governance of the changing conditions of innovation processes, the democratic choice of future technologies, and the limitation of public expenditure linked to decision-making processes. Distribution means leaning on bottom-up processes, while in order to be effective and trustworthy, standards of quality and quality assurance systems need to be developed. In addition, central networking nodes, which facilitate horizontal linkages and the circulation of knowledge between different policy arenas and levels, will be of crucial importance.

In order to carry out effective policy-making, Strategic Intelligence plays a fundamental part. Additionally, standards of quality, the circulation of knowledge and centralized networking are all areas of uppermost importance that should not be ignored

Keywords
evaluation, foresight, technology assessment, innovation policy-making, distributed intelligence

Note

1- This paper is based on a report produced by members of the Advanced Science and Technology Policy Planning Network – a network set up as part of the Targeted Socio-Economic Research Programme of the European Union: Kuhlmann, S., Boekholt, P., Georghiou, L., Guy, K., Héraud, J.-A., Laredo, Ph., Lemola, T., Loveridge, D., Luukkonen, T., Polt, W., Rip, A., Sanz-Menendez, L., Smits, R., *"Improving Distributed Intelligence in Complex Innovation Systems"*, Karlsruhe (Fraunhofer Institute Systems and Innovation Research, ISI), 1999.

References

- Kuhlmann, S., *Evaluation as a Medium of Science & Technology Policy: Recent Developments in Germany and Beyond.* In: OECD (ed.): Policy Evaluation in Innovation and Technology, Towards Best Practices. Paris, 443-460, 1997.
- Martin, B., Foresight in Science and Technology. In: Technology Analysis & Strategic Management vol. 7, no. 2, p140, 1995.
- Schot, J., Rip, A., *The Past and the Future of Constructive Technology Assessment.* (1997) In: Technological Forecasting and Social Change 54, 251-268, 1996.
- Loveridge, D., (Guest Editor) International Journal of Technology Management: Special Publication on Technology Assessment, Vol. 11, Nos 5/6, 1996.
- Airaghi, A., Busch, N., Georghiou, L., Kuhlman, S., Ledoux, J.M., Raan, A., van, Viana Baptista, J., *Options and Limits for Assessing the Socio-Economic Impact of European RTD Programmes.* Report to the European Commission, 1999.
- Guy, K., Clark, J., Balazs, K., Stroyan, J., Arnold, E., *Strategic Options for the Evaluation of the R&D Programmes of the European Union.* Report to the Scientific and Technological Options (STOA) Programme of the European Parliament. Brighton (Technopolis), 1998.
- Fayl, E., Dumont, Y., Durieux, L., Karatzas, I., O'Sullivan, L., *Evaluation of research and technological development programmes: a tool for policy design.* In: Research Evaluation, vol. 7. no. 2, 93-97, 1997.

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Lessons from RTDI Enhancement in Less-Favoured Regions

Lena J. Tsipouri, *University of Athens*

Issue: The relationship between increasing R&D and real economic growth (as well as its evaluation) is more complicated than a simple mathematical equation, and is affected by the propensity to disseminate technology and the ability of economic actors to absorb knowledge. Dissemination and absorptive capabilities are a particular problem in less favoured regions, where behavioural patterns in the face of uncertainties differ from those in core regions.

Relevance: More and more regional, national and transnational funds have been invested in RTDI in the less favoured regions in the last decade. A combination of a set of quantitative indicators and qualitative assessments has been used in the evaluation of RTDI initiatives in the Objective 1 regions of the EU. The results offer a set of lessons both for the regions studied and to some extent help formulate proposals for the future member states.

Introduction[1]

There is no doubt that technology contributes to international competitiveness and, as a consequence, to economic growth and development. All strands of economic thought (Romer 1990, Romer 1986, Grossman and Helpman 1991, Nelson 1993, Dosi 1988, Edquist 1997) converge to this general conclusion, although they often disagree about or plead ignorance as to the precise mechanisms and means to apply in order to achieve these targets. Policy-makers in developed, less favoured and developing countries and regions worldwide are increasingly adopting strategies and measures that incorporate technology-support and endogenous development promotion in their agendas[2], as prescribed by state-of-the-art theory.

Unfortunately, there are no linear or other mathematical functions that determine the rate of return of R&D investments. Policy-makers can decide on research inputs and portfolios of finance but with some uncertainty regarding their results. Thus, although research and development (R&D) inputs are known to be a valuable input for growth and welfare, it is still to a large extent unexplored how exactly they relate to outputs like technology and innovation (T&I). RTDI, used as an interconnected acronym in the Community jargon, is by far not an entity, and, if policies are not adequately designed, one may very well end up by supporting only part of the process[3].

An additional problem to this lack of deterministic knowledge is that the limited evidence that exists is based on measurements and

Although it has been proven that technology contributes to international competitiveness and, subsequently, to economic growth and development, its relation with R&D inputs and their combined effect on results remain very much unexplored

Difficulty exists in transferring existing role-models to less favoured regions due to the limited, biased knowledge available and the existing technical and human resources and policies of the region in question

Results, backed by the belief of European policy-makers that the learning society is the only sustainable growth model for Europe, show that R&D inputs have grown rapidly

experiences of technologically -advanced countries and therefore takes core regions' structures for granted. Thus, enlightened policy-makers intervening to help less favoured regions to become more competitive, with learning society rather than low-wage aspirations, are confronted with a very biased reservoir of knowledge on concrete actions. There is a tendency to launch measures that might prove unsuitable in a new environment. Cumulative effects, the internal dynamics of spillovers and external economies in every region, path dependencies, public and private sector rigidities or inefficiencies and limited degrees of freedom are behind this difficulty of transferring successful models.

The effort to draw conclusions from the core regions experiences starts with a high number of limitations and problem areas: companies in less favoured countries or regions (LFRs)[4] are too small and too traditional to take investment decisions in RTDI or facilitate appropriability. Thus, the most important areas are effective support to *increase spillovers and create externalities* under the limited degrees of freedom allowed by path dependencies. In the same context, changes in the propensity to network are relevant aspects of policy that will lead to benefits of trust and externalities. *Human resources* are, finally, also a key issue for technology development and competitive performance on many levels and from two points of view. Skills are necessary to improve technological capabilities but by the same token, only skilled employees can cope with technological change and thus employment will only increase if an economy disposes of employees able to respond to technological needs. Yet, these two key areas, which appear to be the most relevant, seem also to make the difference between core regions and LFRs. In the former, externalities are automatically created due to long-term patterns of co-operation and mobility, while in the latter, dissemination is difficult due to limited absorptive capabilities and the overall structure of manufacturing and competition.

Empirical evidence from RTDI emphasis in the EU Less -Favoured Regions

RTDI investments in all Objective 1 regions of the EU have grown very rapidly from the first to the second Community Support Framework (CSF). Due to the firm belief of the European policy-makers that the learning society is the only sustainable growth model for Europe, in the long-run, the inputs for R&D have grown fast. In order of magnitude, Table 1 demonstrates that, in absolute terms, they grew 3- to 10-fold, while, in relative terms, they doubled. At the same time, the LFRs increased their participation in the Framework Programme[5] (Sharp 1998) further increasing R&D financial resources. This evolution is fully compatible with recent OECD guidelines (OECD 1998, OECD 1999).

Technology-induced improvements in productivity and employment were less visible than increased inputs. On the contrary, in some cases it is suggested that RTDI funds have not met their targets or have only partly done so (CEC 1997, CEC 1999). At any rate contribution to competitiveness and economic growth has differed considerably. Funds have flown to a large extent towards the creation of R&D infrastructure during the first CSF, and it was not until after the first evaluation that it was strongly recommended to redirect them towards diffusion, systemic interaction of regional actors and the creation of absorptive capabilities. Different degrees of success in this effort were identified. In an extensive evaluation of technology - funding in the Objective 1 and Objective 6 areas (CIRCA et al. 1999), it was found that, overall, the absorption of technology funds improves in LFRs, but that conventions need, in most cases, to be

Table 1. Evolution of CSF funds dedicated to RTD, Objective 1, 2 and 6, selected countries (in MECU and %)

	Total 1989-93	RTD EU	% RTD	Total 1994-99	RTD EU	% RTD
Germany	3536	98	2.76	15206	945	6.21
Greece	7528	68	0.9	13980	592	4.23
Spain	11677	366	3.13	28715	1821	6.34
Italy	8891	518	5.83	16322	1148	7.03
Ireland	4460	166	7.73	5620	316	5.62
Portugal	8450	382	4.53	13980	963	6.89
Total EU*	49948	1984	3.97	110021	7686	6.99

* The total includes few additional LFRs in core countries and is thus higher than the sum of the selected countries presented.

Source: European Report on Science and Technology Indicators, p. 389.

radically changed to help those regions pass from a cheap labour advantage to a learning society.

In an effort to systematically analyse and compare RTDI inputs and outputs in the LFRs the study identified five categories of expenditure.

Although of a very broad nature, several conclusions can be drawn from Table 2. First of all, the infrastructure and equipment category still absorbs a third of all RTDI funds, despite the tendency and commitment to move towards soft actions. A basic difference from the first CSF is the increase in private research activities. In this period the higher productivity and effectiveness of business research is widely recognized and is amply financed. What seems to still suffer considerably is the academic category promoted by all recent academic evidence (Porter 1990, Best 1990): technology transfer, innovation and networking. Although all member states and regions recognized external economies as the source of technology spillovers and, as a consequence, the key way to link R&D inputs and innovation and competitiveness, little was done in this area. Not only were the means relatively scarce, but a more detailed analysis within this category demonstrates that member states and regions, often positioned in this category, support services of dubious relevance to local networks.

Although the results show that the absorption of technical funds has improved in LFRs, the need exists to radically change conventions to help regions pass from a cheap labour rationale to a learning society one

Whereas there has been an increase in the funding of private research activities, Technology Transfer, Innovation and Networking, although recognized as fundamental to competitiveness and economic growth, continue to suffer from low investment

Table 2. Broad categories of RTDI expenditure in Objective 1 and Objective 6 regions under the second CSF

Category	Share (all Obj. 1 and Obj. 6)
Infrastructure and equipment	29.7
Public research activities	14.6
Private research activities	35.6
Technology Transfer, Innovation and Networking (public focus)	13.4
Counselling and advisory services (industry focused)	0.4
Human potential, education and training	6.3
Total	**100**

Source: CIRCA et al. 1999.

Less favoured regións become very competitive through the rapid and appropriate adaptation of new knowledge

Although diffusion is seen as the driving force which is best adapted to LFRs it is, however, difficult to implement

Worse still, dissemination for the sake of dissemination and networking for the sake of networking were frequently observed, instead of linking their funding with their linkage with businesses. Last but not least, one immediately sees the very low level of advisory services, a generally recognized priority in SME needs.

Issues and results of the evaluation

Inputs were identified with growth potential , but the crucial question remains: to what extent, how and under what circumstances can these RTD inputs be effectively used to produce economic growth? Otherwise they are only a means to strengthen the research system.

Technology can be a driving force behind economic development if:

- it leads big or technologically leading companies to appropriate results early in the life cycle of products and thus benefit from above average rents (appropriability)
- it helps individual companies defend their market shares or moderately increase them through adaptation to technological change (individual support measures for innovation and technology transfer)
- it creates spillovers that lead to externalities benefiting the whole region (successful diffusion).

Research and technology policies, which are designed to create new knowledge, address the first of the three points raised above. Innovation and technology transfer policies are related but different. Their target is the commercialization of new products, processes or organizational forms, which are new to their environment but not necessarily state of the art. Innovation is the cornerstone of competition in the learning economy, but companies can be very innovative without major research efforts. Even under the most optimistic scenarios LFRs are unlikely to demonstrate commercial success in state-of-the-art research, yet they can become very competitive through the rapid and appropriate adaptation of new knowledge. Thus, policies should concentrate on the sustainability of individual competitiveness (a positive, yet moderate effect to overall regional growth) and on diffusion and the creation of externalities. The difficulty lies now in concentrating on this third aspect of diffusion. Two issues can be raised:

- Academic and industrial research teams are actively documenting the need for measures supporting capacity-enhancement, considering it as a first step that will then act as a catalyst for the diffusion of knowledge, regardless of the vicissitudes of the "linear model" in academic analyses. This capacity emphasis by research teams was stronger under the first CSF and although it was sometimes maintained in the second, it was complemented with measures supporting networking and cluster creation, as well as diffusion mechanisms.

- Often diffusion mechanisms themselves attract all the attention and the creation of databases, forums, demonstrations and contact points become the target instead of the means. There is little knowledge about the ultimate success of dissemination mechanisms and detailed evaluation would be too costly to pursue.

As a result, one may assume that from the three driving forces mentioned at the beginning of this section only the last one is likely to be the one best adapted to the structures of less-favoured economies and, in addition, this last one is the most difficult to implement. Systematic search in all the EU Objective 1 regions in the form of quantitative evidence combined with case-study research was used to identify and put together the relevant parameters of the successful cases and regions studied, in order to be transferred and have a positive impact elsewhere.

The most striking results of this experience were that, although many countries and regions had adopted similar schemes, only a few were identified as successful cases. Using evidence from absorption, mobilization of latent demand and related income- generation plus rating from business users, the good practices identified were the following:

1. *On agencies and schemes supporting the management of RTDI resources*: Good management for policy implementation by the Irish Forbairt.
2. *Good linkage between State and Regional Authorities*: in the French Scheme of Regional Delegates on Research and Technology.
3. *On industry support schemes*: Measure 1 in Ireland.
4. *On the idea of shifting from grant to equity or repayable loans*: CDTI in Spain, Equity considerations in Ireland.
5. *On the activation of the private sector*: The Federation of Industries of Northern Greece, The Industrial Research Group in Ireland.
6. *On the way to improve capacity utilization through co-operation*: The Irish PATs, The Northern Irish ATCs, The Portuguese Research Associations in the region of Norte.
7. *On clustering as the best means to increase spillovers*: Clustering in Saxony.

Regrouping these best practices with the six key themes of the evaluation (capacity enhancement, innovation promotion, management, learning, funding and policy orientation.) it appears on Table 3, and looking at their primary (P) and secondary objectives (S), that national and regional governments put more emphasis on management, innovation and funding and less on learning and policies. Yet it is the latter that appear in all types of recommendations, be it through the systemic approaches or be it through the externalities concepts of the neo-classical theory.

The limited success stories, geographically over-concentrated in Ireland, demonstrate that a good administration can be very effective in transferring practices. But countries and regions have to select "from whom" to learn and "what" to learn, as the transferability conditions appear to be more important than the effectiveness of each particular scheme.

The success stories geographically demonstrate that a good administration can be very effective in transferring practices. But transferability conditions appear to be more important than the effectiveness of each particular scheme

Table 3. Good practices by theme and their primary (CP) and secondary (S) objectives/outcomes

	Capacity	Innovation	Management	Learning	Funding	Policy
Forbairt	P		S		P	P
Regional Delegates			P			S
CDTI		P	P		P	
Equity funds			P			
Measure I	S	P	P		P	
ATCs	P	P	P	S	S	
PATs	P	P	P	S	S	
Norte		P		S		
Federation of Industry CM			S	P		P
IRDG		P			S	
Clusters in Saxony		P		P		

Source: CIRCA et al.

The lack of practical knowledge, experimentation and policy-copying hinder possible improvements. Help is needed in benchmarking, clarifying objectives and increasing social acceptance

Successful case studies highlight the need to increase absorptive capabilities and enhance the techniques and culture of evaluation to overcome the tendency to substitute accounting for evaluation

Conclusions

To date, the EU's contribution to emphasizing technology as a key component of regional development has been very important. But, the lack of practical knowledge and experimentation, and the tendency of policy to copy rather than tailor make measures, proves that much remains to be done. RTDI has become a key component in regional development policies, yet, as in all cases of intangible investments, its effective implementation is more difficult than in tangible ones. There are important steps that the Structural Funds can take to further improve RTDI funding in LFRs: help benchmarking, help clarify objectives through alternative indicators, increase social acceptance through training and offer "policy minded" studies.

Particular emphasis needs to be given to absorptive capabilities in LFRs. Thus the idea of successfully *increasing absorptive capabilities* (Cohen and Levinthal 1989) becomes central to technology policies in Objective 1 regions. Evaluation techniques and the evaluation culture need to be further enhanced, as it was found that, in most cases, there is a tendency to substitute evaluation with accounting. The most important result of such an exercise is feedback within the same region and the transfer of good practices. Successful case studies were identified, in particular those separating policy from management, which contributed to increased efficiency and those enhancing interaction and thus diminishing systemic failures. But transfer of good practice is not easy, as the environmental conditions dictate the ultimate success of specific measures.

Keywords

RTDI investment, less-favoured regions, capacity enhancement, innovation promotion, funding and policy orientation

Notes

1- This paper draws substantial ideas from the "Thematic evaluation of the impacts of Structural Funds 1994/99 on research, technology development and innovation (RTDI) in Objective 1 and 6 regions" prepared and coordinated by CIRCA-Dublin, Lena Tsipouri-University of Athens and PriceWaterhouse-Coopers, The Hague.

2- For a thorough survey on these issues see Amin, OECD, European Commission.

3- Although there is broad theoretical agreement that the linear process is an over simplification of the real world, and thus one cannot expect R&D inputs to automatically result to technological upgrading of the production process, there is little evidence of policy makers doing something radically different than that.

4- The acronym LFRs, used in the EU to characterise regions with GDP/head lower than 75% of EU average is used here to cover equally whole countries (like Greece, Portugal and until the end of this century Ireland) but also poor regions in wealthy countries, like Southern Italy or the less prosperous parts of Spain. From a broader academic point of view the notion refers to areas that have crossed the barriers of underdevelopment, dispose of a general infrastructure and education but are not competitive in the global market, as their specialisation deals with low wages rather than learning.

5- In contrast to the CSF, where funds are allocated with regional development criteria, favouring the LFRs, the Framework Programme distributes funds on a merit basis after peer reviewing proposals, independently of the origin of the proposers.

References

- Best, M., *The New Competition*, Cambridge, Polity Press, 1990.
- CIRCA-Dublin, Tsipouri, L., University of Athens and PriceWaterhouse-Coopers, The Hague, *Thematic evaluation of the impacts of Structural Funds (1994/99) on research, technology development and innovation (RTDI) in Objective 1 and 6 regions,* A Report to the European Commission, DG-XVI, 1999.
- Cohen, W., Levinthal, R., *Innovation and learning: the two faces of R&D,* Economic Journal 99, 569-96, 1989.
- Dosi, G., *et al,* (eds), *Technical Change and Economic Theory,* London, Pinter.
- Edquist, C., *Systems of Innovation,* Pinter. London and Washington, 1997.
- European Commission, *Second European Report on Science and Technology Indicators,* Luxembourg, Office of Official Publications, 1997.
- European Commission, *Sixth Periodic Report on European Cohesion,* Luxembourg, Office of Official Publications (in Greek), 1999.
- Nelson, R. R., (ed.) *National Innovation System: A comparative study,* Oxford, Oxford University Press.
- Grossman, G., Helpman, E., *Innovation and Growth in the Global Economy,* Cambridge, Mass, MIT Press, 1991.
- OECD, *Technology, Productivity and Job Creation,* Paris, 1998.
- OECD, *Report on Innovation and Territories: Upgrading knowledge and diffusing technology in a regional context,* DT/TDPC (99)8, Paris.
- Porter, M., *The Competitive Advantage of Nations,* Free Press, New York, 1990.
- Romer, P.M., "Endogenous technological change" *Journal of Political Economy* 98(5), 71-102, 1990.
- Romer, P., "Increasing returns and long-run growth" *Journal of Political Economy* 94, 1002-37, 1986.
- Sharp, M., *Competitiveness and Cohesion - are the two compatible*? Research Policy 27, p. 569-588, 1998.

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Lena J.Tsipouri studied economic sciences at the University of Athens (Diploma), economic sciences and computer applications (Betriebsinformatik) at the University of Vienna and took her PhD (Doctorat d' Etat) at the University of Paris II. She also received a Fulbright postdoctoral research award from MIT/Cambridge Massachusetts. Since 1993 she has been an assistant professor at the University of Athens, Department of Economic Sciences. She has also served as an Economic consultant at the Ministry of National Economy (1978-85), and as a Scientific collaborator at the International Institute for Applied System Analysis in Vienna (1977-78). Recent publications and scientific research concentrate on the areas of technological change, in particular the role of infrastructure and public policy.

Evaluating the Scientific Excellence of Research Programmes: a Pivot of Decision-Making

Anthony F.J. van Raan, *Centre for Science and Technology Studies, University of Leiden*

Issue: Excellent scientific work is the driving force behind S&T breakthroughs. Policy-makers and research managers maintain that they are well aware of the places of excellence, as they are informed by "experts". Expert opinions, however, may be influenced by subjective factors, narrow-mindedness and limited cognitive horizons.

Relevance: A method is proposed, enabling identification, with a high probability of accuracy, scientific excellence in any particular field of R&D and providing a map of all major scientific developments directly relevant to that field. The mapping approach even provides the possibility of foresight. Particularly at the level of research programmes, the method could be an indispensable tool for decision-making in science policy and priority setting.

Subjective aspects are not merely negative elements. In any judgement there must be room for the intuitive insights of experts

The search for excellence

The overall process of R&D evaluation, particularly the elements concerning research performance, generally consists of two main components, continuous monitoring and ex-post assessment. The method presented in this paper offers a novel, powerful instrument for both components.

Peer review undoubtedly has to remain the principal procedure of scientific quality judgement in the framework of *ex-post* assessment. But peer review and all related expert-based judgements have serious shortcomings and disadvantages (Moxham and Anderson, 1992). The major problem is, as is well known, subjectivity, i.e., dependence of the outcomes on the choice of individual peer reviewers. This dependence may result in conflicts of interests, a lack of awareness of quality or a negative bias against younger people and newcomers to the field. A remarkable new disadvantage of peer review was discovered in our recent studies: the apparent inability or perhaps unwillingness to distinguish clearly *between top and less-than top* research performance (Rinia et al 1998). Bibliometric assessment is not infected by such crucial disadvantages. Particularly in these times of emerging new fields and increasing interdisciplinarity, it is not easy for peers to form a valid opinion on the performance of those they are evaluating.

The most crucial parameter in the assessment of research performance is *international scientific influence*. This article addresses recently developed standardized procedures based on advanced bibliometric methods to unambiguously establish scientific excellence. Undoubtedly, the bibliometric approach is not an ideal instrument, nor one which works perfectly in all fields under all circumstances. But the approach works well in the large majority of the natural, medical, applied and behavioural sciences. These fields of science are among the most cost-intensive and arguably the ones with the strongest socio-economic impact. The central question to be answered is whether the performance is *high* or *low*, and in the case of scientific excellence, *very high*. Thus, measures are necessary to identify and assess extraordinary performance, particularly when there are signs that expert-based judgement alone may not be able to realize this crucial assessment.

Bibliometric assessment of research performance is based on one central assumption: scientists who have something important to say publish vigorously in the open, international academic journal literature. Our central statement, based on considerable experience, is that the search for scientific excellence should be performed systematically at the "meso"-level (i.e. larger institutions, such as universities or major parts of universities, such as large faculties or institutes). Also divisions of large national research organizations, e.g., the medical or physics division of research councils, are suitable levels to start the *search for excellence*. After an overall assessment of these larger institutions, the performance analysis can be narrowed down to research groups and programmes within these institutions.

The reason for the choice of the meso-level of the institution is that on the input-side all necessary information, particularly data on personnel and on the composition of groups and programmes, are readily available. Such institutional infrastructure data are not available in general publication databases but must always be collected separately in relation the institutions concerned. Bibliometric analyses performed at the macro-level (e.g., a whole country) yield at best general assessments of fields as a whole, for instance, how good a country's performance is in physics, chemistry, psychology or immunology, *without* a reliable breakdown into the individual research groups or programmes.

Therefore, if one wants to identify scientific excellence, one has to opt for the institutional level. This is simply because scientific research is mostly conducted by groups, whether large or small, embedded in a specific institution. Thus, the institution is the starting point from which to accurately identify and monitor scientific performance in such a way that it is directly policy-relevant (e.g. the location of the groups deserving support on account of their high quality).

Outline of the method

The core of the bibliometric approach can be described as follows: Communication, i.e., exchange of research results, is a crucial aspect of the scientific endeavour. Publications are not the only factor, but they are certainly a very important component of the knowledge exchange process. Work of high quality provokes reactions from colleague scientists. These make up an international forum, the "invisible college", in which research results are discussed. In most cases, these colleague scientists play their role as members of the invisible college by referring in their own work to earlier work of other scientists. The process of citation is a complex one, and it certainly does not provide an "ideal" monitor of scientific performance. This is particularly the case on a statistically low aggregation level, e.g., just one publication. But the application of citation-analysis to the work, the

For a substantial improvement of decision-making the proposed bibliometric method has to be used in parallel with expert-based evaluation procedures

The institution is the starting point from which to accurately identify and monitor scientific performance in such a way that it is directly policy-relevant (e.g. pinpointing high-quality groups) "*oeuvre*" *of a group as a whole over a longer period of time*, could yield, in many situations, a strong indicator of scientific performance, and in particular of scientific quality. One essential condition is that applied citation-analysis is part of an advanced, technically highly developed bibliometric method. As discussed above, this paper will not discuss the basics of this methodology, as it is described in great detail in recent overview papers (Van Raan 1996, 1999). The paper focuses on one specific "crown" indicator, which relates the measured impact of a research group or institute to a worldwide, field-specific reference value. It is the *international standardized impact indicator* as discussed extensively in our recent work (the indicator ***CPP/FCSm***[1]). This indicator enables us to observe immediately whether the performance of a research group or institute is far below (indicator value < 0.5), below (indicator value 0.5 - 0.8), around (0.8 - 1.2), above (1.2 - 2.0), or far above (>2.0) the international (western world) dominated impact standard of the field. In the latter case, a measured impact far above the international standard, provides a very strong indication of high quality. In other words, by searching for research groups with an impact above a specific threshold value, scientific excellence can be detected and monitored.

By searching for research groups with an impact above a specific threshold value, scientific excellence can be detected and monitored

We are developing analytical procedures to efficiently conduct such searches on a large scale. For instance, in the European Union this would mean a bibliometric analysis in each member country on the level of larger institutions (universities, organizations such as the British Medical Research Council, the French CNRS, the German Max-Planck Society). On the basis of the internal structure of these institutions, a survey of the institutional groups is the next and "decisive" step. Highly automated routines are essential to carry out these performance assessments as efficiently as possible.

Examples of results

In this paper the application of our method is discussed on the basis of "real life" examples. First the results for a large medical faculty including a university hospital are presented. Next a short presentation is given of a similar analysis in the physics division of a national research organization. The assessments are based on the CPP/FCSm indicator, denoted in this paper by ***IMPACT***.

Table 1 shows a performance trend analysis of the medical faculty and university hospital of an established and renowned university in a European Union member state. As a first but good indication of size also the number of publications (in international, refereed journals, as defined in Van Raan 1996, 1999) is given. This number is about 1,000 per year.

Table 1. Overall Institutional Survey

Trend analysis of size in terms in publication output PUBL and of the international standardized IMPAC

Time period	PUBL	IMPACT
1988-1991	3,637	1.28
1989-1992	3,891	1.25
1990-1993	3,988	1.22
1991-1994	4,209	1.16
1992-1995	4,433	1.19
1993-1996	4,559	1.26
1994-1997	4,665	1.34

The higher the aggregation level, the larger the volume in publications and the more difficult it is to have an impact significantly above the international level. At the "meso-level", an ***IMPACT*** value above 1.2, such as in this case, means that the institution concerned can be considered a scientifically strong organization, with a high probability of finding very good to excellent groups. Thus, the next step in the *search for excellence* is the breakdown of the institution into smaller units, i.e., research groups and/or programmes. Therefore the bibliometric analysis has to be applied on the basis of institutional input data on personnel and composition of groups.

The medical faculty provided the names of all senior researchers, from 1988, as far as they still are employed in 1998, and the allocation of these researchers over all research groups and programmes (about 100). The bibliometric algorithms can now be repeated efficiently on the lowest but most important aggregation level, that of the research group or research programme. In most cases the volume of publications at this level is between 10 and 20 per year. Groups with ***IMPACT*** value > 3.0 can compete easily in their field *with top-groups at top US universities.* If the threshold value for the ***IMPACT*** indicator is set at 3.0, we filter out the excellent groups with high probability of obtaining accurate results.

As an example, we shall focus on the last time period of the trend analysis (1994-1997, the data has been updated for the period 1996-1999). The following groups, presented in Table 2, are identified immediately.

In this way five out of the about 100 research groups and programmes that can be regarded as excellent are identified. Ten groups have an ***IMPACT*** value between 2.0 and 3.0, which classifies them as very good. In total, there are 29 groups with an ***IMPACT*** value above 1.5.

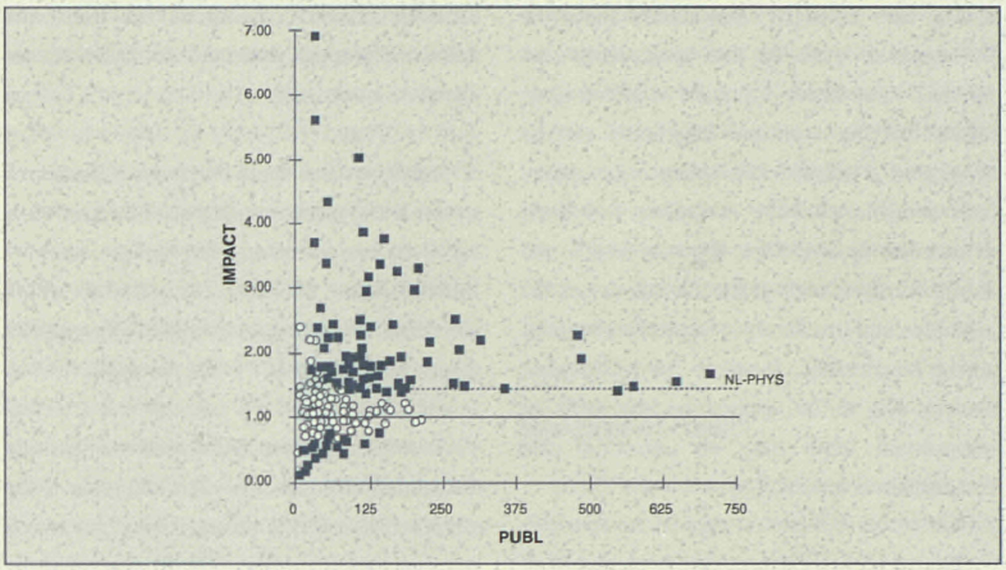
A further illustration of the method is given in the second example. Here the institution is the physics division of a national research council (van Leeuwen et al 1996). This division has about 200 research groups and programmes. The results of an assessment covering the ten-year period 1985-1994 are presented here. An update assessment for 1996-1999 is in preparation.

Both the volume of publications and the ***IMPACT*** values for all 200 groups/programmes are shown in Fig. 1. We easily observe 13 excellent research groups/programmes, i.e., with ***IMPACT*** value > 3.0. These groups can be identified immediately according to the encoding given by the research council and used in the analysis. The figure nicely illustrates a general finding discussed earlier: the larger the unit, the more the average

Table 2. The search for Scientific Excellence

Research group	PUBL	IMPACT > 3.0
Blood research: thrombosis, genetic coagulation factors	111	4.32
Immuno-genetics: cell membranes, HLA	30	3.12
Medical imaging	56	4.27
Clinical Epidemiology	169	4.23
Molecular and Genetic Tumour-pathology	144	3.49

Figure 1. Overall Institutional Survey and The Search for Scientific Excellence combined



The abscissa gives the number of papers, the ordinate the value of the **IMPACT** indicator. Open circles: groups/programmes with impact not significantly different from the international standard which is indicated by the horizontal solid line (**IMPACT** = 1). Black squares: groups/programmes above (below) the international standard. The dotted line represents the average (**IMPACT** = 1.45) of the total of the about 200 physics groups/programmes in the physics division of the national research council involved.

It is important to split up larger groups and programmes into smaller groups to allow a more precise impact assessment. Otherwise, excellent work will be "hidden" within the bulk of a large group/programme

impact of the unit tends to lower (more "average") values. Therefore it is important to split up larger groups and programmes into smaller groups to allow a more precise impact assessment. Otherwise, excellent work will be "hidden" within the bulk of a large group/programme.

Landscapes of science: Bibliometric mapping

To conclude, we will take a look at a second major line of advanced bibliometric methodology: bibliometric mapping. (For a more detailed discussion see Noyons and Van Raan, 1998). The basic idea is the following. Each year about a million scientific articles are published. For just one research field, such as micro-electronics, the number of papers is already many thousands per year. This gives you an impression of the enormous size of current scientific output. How is it possible to keep track of all these developments? Are there cognitive structures "hidden" at a "meta-level" in this mass of published knowledge?

Suppose each research field can be characterized by a list of the 100 (for example) most important, keywords. For micro-electronics research such a list will cover words like circuits, electronic structures, lasers, telecommunication, opto-electronic devices, radio and television, superconductivity, and so on. Each publication can be characterized by a subset from the total list of keywords. For all micro-electronic publications, keyword-lists are compared pair-wise. In other words, these many thousand publications constitute a gigantic network in which all publications are linked together by one of more common keywords. The more keywords two publications have in common, the more these publications are related (keyword-similarity) and thus belong to the same research area or research speciality. In mathematical terms, publications are represented as vectors in a multi-dimensional word-space. In this space they group together, or take very distant positions when they are not related to each other.

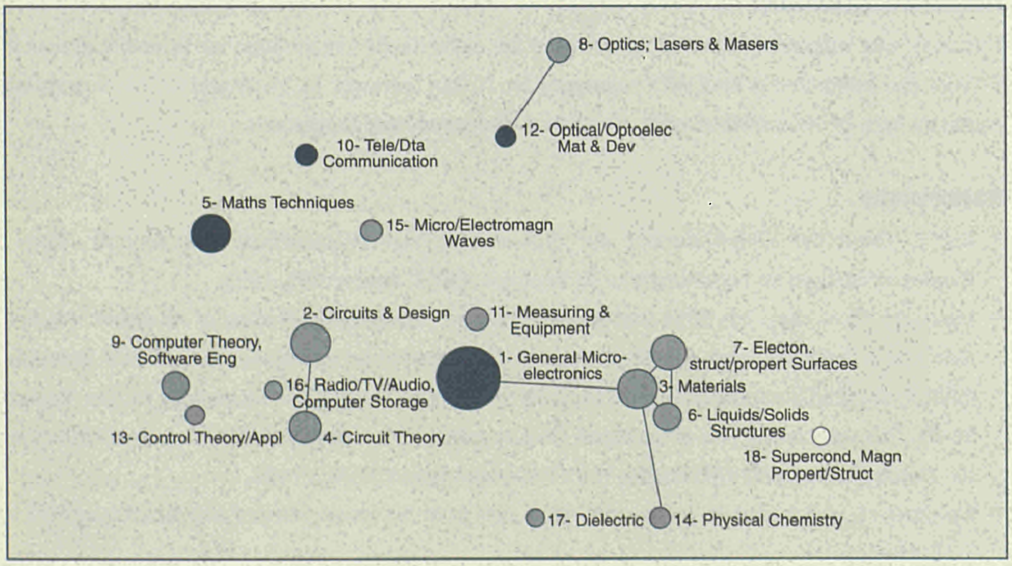
Special mathematical techniques have been developed to unravel these publication networks, to cluster related publications, and to map the total of clusters in a two-dimensional space in order to reveal an underlying structure. The fascinating point is that these structures can be regarded as the cognitive, or intellectual structure of science. Clusters can be identified as sub-fields and research themes. As discussed above, the procedure is entirely based on the total of relations between all publications. Thus, the structures that are discovered are not the result of any pre-arranged classification system. Nobody prescribed these structures. The structures emerge solely from the internal relations of the whole universe of publications together (given the choice of keywords by the analysts). In other words, what is made visible by our mathematical methods, is the self-organized structure of science. In Figure 2, the result for micro-electronics research is shown (Noyons et al 1998). The map clearly shows 18 identified sub-fields in their mutual relationships. The closer the clusters are, the more closely related the sub-fields represented by these clusters. Major sub-fields such as general micro-electronics, circuits and design, materials, circuit theory, mathematical techniques, liquids, and structure of solids can be observed.

Concluding remarks

In this article we have discussed an advanced method for the clear, objective identification of scientific excellence. These bibliometric performance indicators offer a useful complement

Mathematical techniques have been developed to unravel publication networks, to cluster related publications, and to map the total of clusters in a two-dimensional space in order to reveal an underlying structure

Figure 2. Bibliometric map based on shared-word analysis of micro-electronics research, 1992-1994



The map essentially represents a relational structure of clusters of publications, based on cluster-similarity measures. The clusters can be identified as research fields. The closer the clusters are, the more closely related the fields concerned. "White" clusters are characterized by decreasing publication activity (worldwide), dark grey clusters by increasing activity.

to other evaluation approaches. Bibliometric mapping is a powerful tool for visualizing the cognitive landscape of an R&D field and its surrounding environment. Maps made over a series of years reveal trends and changes in structure, and extrapolation of a map series can act as a "foresight" system for near-future R&D developments.

Furthermore, the position of actors can be put on the map. Thus a strategic map is created: who is where in science? With help of the performance indicators we are able to identify the strongest players. Thus, the combination of performance assessment and mapping appears to be a very powerful tool in the evaluation of research activities.

Changes in maps over time (field structure, position of actors) may indicate the impact in bibliometric terms of R&D programmes, particularly with respect to sub-fields characterized by research around social and economic problems. Thus the mapping methodology is also applicable when examining socio-economic studies of the impact of R&D.

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Keywords
research performance, scientific excellence, science policy decision-making, bibliometric method, reinforcement of peer review

Note

1- Number of "external" citations received by the group or institute per publication over the given period of time *(**CPP**)*, normalized to same parameter worldwide (***FCSm***). See Van Raan 1996, 1999.

Our website is at **http://sahara.fsw.leidenuniv.nl/cwts/cwtshome.html**

Acknowledgements
This work was supported in part by grants from the Netherlands Organisation for Scientific Research (NWO). The author thanks his CWTS colleagues Th. N. Van Leeuwen, M. Visser and E.C.M. Noyons for important parts of the analytical work, stimulating discussions and suggestions.

References

- BMFT. *Deutscher Delphi-Bericht zur Entwicklung von Wissenschaft und Technik.* Bonn: Bundesministerium für Forschung und Technologie (BMFT, now BMBF), 1993.
- Leeuwen, Th.N. van, E.J. Rinia and Raan, A.F.J. van, *Bibliometric Profiles of Academic Physics Research in the Netherlands.* Research Report to the Netherlands Organization for Scientific Research (NWO), Physics Division (FOM), Utrecht. Leiden: Centre for Science and Technology Studies, Report 96-09. This work is also part of the report *Quality Assessment of Research: An Analysis of Physics in the Dutch (Netherlands) Universities in the Nineties.* Utrecht: VSNU, 1996.
- Moxham, H., and Anderson, J., *Peer review. A view from the inside.* Science and Technology Policy 7-15, 1992.
- Noyons, E.C.M., and Raan, A.F.J. van, *Monitoring Scientific Developments from a Dynamic Perspective: Self-Organized Structuring to Map Neural Network Research.* Journal of the American Society for Information Science (JASIS), 49, 68-81, 1998.

- Noyons, E.C.M., Luwel, M., and Moed, H.F., *Combining Mapping and Citation Analysis for Evaluative Bibliometric Purpose. A Bibliometric Study on Recent Development in Micro-Electronics.* Research Policy, to be published 1999.
- Raan, A.F.J. van, *Advanced Bibliometric Methods as Quantitative Core of Peer Review Based Evaluation and Foresight Exercises. Scientometrics* 36, 397-420, 1996.
- Raan, A.F.J., va, *Evaluation of Performance and Trends in Basic and Applied Research by Advanced Bibliometric Methods: A Science Policy Instrument for Nations with an Economy in Transition.* In: Paces, V., Pivec, L., and Teich, A.H., (Eds.). Science Evaluation and Its Management. Proceedings of the NATO Advanced Research Workshop, Prague, November 1997. Amsterdam: IOS Press, 1999.
- Rinia, E.J., Leeuwen, Th.N. van, Vuren, H.G. van, and Raan, A.F.J. van, *Comparative Analysis of A Set of Bibliometric Indicators And Central Peer Review Criteria. Evaluation of Condensed Matter Physics in the Netherlands.* Research Policy 27, 95-107, 1998.

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Evaluating the Impact of Technology Transfers from Public Research Laboratories to Private Firms

Serge Petit, *IMRI*, Vincent Vigneron, *CEMIF*

Issue: Research laboratories are increasingly coming under pressure to evaluate the economic impact of their research. In many cases it is unclear which criteria should be used for these evaluations, and exploratory steps need to be taken.

Relevance: Existing evaluation indicators are poorly equipped to grasp the essential characteristics of innovative activities. Results of recent research suggest there are certain stable patterns linking various types of impacts and their determinants.

Technology can be thought of as comprising three separable components: the "artefact" component, or improvements in production techniques, together with skills and knowledge. Evaluation tends to concentrate only on the first of these

The theoretical background

The theoretical argument that underlies this paper is the acknowledgement that technology cannot be reduced to a piece of formalized information, but that technology is made of three constituents that can exist independently of each other, and each can impact firms on different levels. The "artefact" dimension is the aspect that evaluation is often most concerned with, since improvements in production techniques are perceived to be a *sine qua non* in the ongoing search for industrial competitiveness. But the other dimensions, namely skills and knowledge, are often left out, despite technological development's heavy reliance upon them. In fact, disembodied knowledge spills over more easily (to other activities) than knowledge embodied in use-specific products. This legitimates the idea that the impact of technology is likely to extend beyond the scope of traditional evaluation. Add to that the possibilities for technological recombinations, and then technology ends up as a potentially pervasive phenomenon that is generally improperly captured by the prevailing indicators[1]. This article puts forward complementary evaluation indicators.

The empirical research: data collection and methodology

It is clear that this renewed conception of evaluation cannot be thought of independently of new methods of data collection and processing. A purely *confirmatory* evaluation checking whether predefined objectives have been met appears to be inadequate for two reasons:

1. There is a lack of clearly formulated collaboration objectives. Official programme objectives

are usually too general (contribution to industrial wealth creation and unemployment reduction) to be used for individual project evaluations. The laboratories working guidelines are exclusively formulated in technical terms. The collaboration contracts between the laboratories and the contracting firms, in most cases, do not mention any specific objectives either. Thus, it is unclear which criteria projects could be evaluated against.

2. Lacking the experience of former evaluations and considering the properties of technology, it would be over hasty to assume that no surprising results could emerge from R&D collaborations. Hence reducing the "domain" of possible impacts according to predefined criteria seems a questionable way of proceeding.

Hence, an *exploratory* evaluation is necessary. An evaluation of this type has been carried out based on a sample of twenty-two R&D collaborations between CEA laboratories and firms of different sizes. All collaborations have taken place between 1975 and 1994, allowing for at least four years of commercial exploitation before evaluation. The technological domains covered are very diverse (microelectronics, opto-electronics, materials sciences, industrial process optimization, etc.). For the details of the sample, see Table 1.

Empirical data were gathered through a series of monographs that included document analysis and face-to-face interviews with project leaders. Instead of relying on an exclusively pre-set formal

The face-to-face interviews have made it possible to grasp contextual —often highly qualitative— elements that are necessary to understand the relationship between the laboratory and the firm

Table 1. The sample content (code of company name, transferred technology, data of R&D collaboration)

Event	Partner firm	Technology transferred	R&D collaboration details
1	ALC1	Engraving processes	84-88
2	ALC2	Reactors	84-87
3	BRU	Cytoflourimetry	82-84
4	CEN	Massively parallel processing	91-94
5	COR	Hygrometer	80-81
6	IBA	Electron accelerator	91-93
7	IC	X tomography	83-86
8	SGM2	Massively parallel processing	93-97
9	SGM1	Bubble memories	76-80//88-89
10	SCA	Strain gauges	79-80
11	SES	Polishing process	94-95
12	SOP1	Location electronics	86-87
13	SOP2	Rectangular detector	87-88
14	SOP3	Specialized electronics	89-93
15	TCS	Monolayer CCD	86-92
16	DEN	Wood densification	87-95
17	NIP	PVD coating	82-87
18	SGI	PVD	86-87
19	SICN1	PVD	86-88
20	SICN2	PVC	90-92
21	T+C	Bimetal junctions	81-85
22	VIC	Plate junctions	78-84

methodology, the logical requirements of the task have been explored. General topics (motivations to collaborate, merits of CEA technology, induced effects, etc.) have been investigated along with the answers to precise pre-formulated questions. The face-to-face interviews have made it possible to grasp contextual -often highly qualitative- elements that are necessary to understand the relationship between the laboratory and the firm.

In general there is little data available on R&D collaborations apart from that given in the archived contracts. The memory of the early collaborations is progressively vanishing as the people involved retired or moved on to new jobs. Retrospectively, access to data has proved to be a labour-intensive and time-consuming exercise.

The results of the study include both evaluation indicators that account for the impact of R&D collaborations and the functional relationships between them

The quality of insight into the different companies is uneven, depending on the number of people that were prepared to participate (between 2 and 7 per monograph). In order to have the most reliable information possible, participants were asked to validate the written report of the interview. As a general rule, the targeted participants were the projects leaders themselves, whether in the laboratory or in the firm. Generally speaking, their cooperation was good considering that the collaborations often lay far back in time.

The indicators are constructed through a sort of "dialogue" between the empirical evidence gathered and the more conceptual and theoretical requirements of the evaluation literature

The results

Two levels of results were established:

1. evaluation indicators that account for the impact of R&D collaborations were elaborated;

2. functional relationships between these impact indicators and a set of structural variables (such as the profile of the firm, the configuration of the collaboration, and the type of innovation that the company wished to launch with the laboratory's support) were established.

Constructing impact indicators

Based on a set of empirical observations[2], variables have been elaborated that are not the result of an aggregation of individual effects into a single metric, but so-called "conceptual contractions", mapping effects induced by innovation onto a set of evaluation criteria. The procedure rests on the experience and "naturalistic generalization"[3] of one's accumulated tacit knowledge as an evaluator that makes it possible to deal with hard-to-quantify aspects (e.g. to understand metaphors). "Tacit knowledge includes a multitude of inexpressible associations that give rise to new meanings, new ideas, and new applications of the old[4]". Of course, this way of proceeding may not include all the individual effects, but as the elaborated criteria are meant to serve as a methodological basis for future evaluations, a certain level of generality has to be accepted.

The indicators are constructed through a sort of "dialogue" between the empirical evidence gathered and the more conceptual and theoretical requirements of the evaluation literature.

There are two types of indicator:

The first set of indicators is supposed to reflect the *project's contribution to the achievement of the mission's overall objectives*. The following indicators were selected:

- the *innovation-induced turnover* related to the turnover of the concerned business unit (CAi);
- the *durability* of the average innovation-related turnover (PERCAi);
- the effect of innovation on the firm's *employment* level (EMB).

The second set of indicators takes into account *recurrent effects* of R&D collaborations that are not accounted for by the first set. Four indicators were selected:

- the level of *capitalization* on transferred knowledge (CAP);

- the level of *intrafirm diffusion* (EXT);
- the *reputation* effects (REPUT);
- the effect on the firm's *competence building* (FONDS).

However, the procedure used is open to challenge:

1. one can argue that it is not the evaluator's role to set the evaluation criteria;

2. the construction of monograph-based criteria/ variables based on "naturalistic generalization" depends on the unique experience of the evaluator. Considering the lack of data, there is hardly any way around this.

The elaboration of the various impact dimensions is a first result of the empirical analysis, based on the need to grasp technology and innovation in their material and immaterial dimensions.

The links between the impacts and their determinants

This study is not limited to describing the impacts. Each R&D collaboration in the sample is described through an array of variables that supposedly intervene in the generation of these impacts. There are three "blocks" of variables:

- the "profile of the firm" is described by its *size* (SIZ) and its *skill base* (COMPE);

- the "collaboration" is described by the *type of relationship* (REL), the *organizational configuration* (CONFIG), the *position of the collaboration* in the innovation process (POS) and its *complexity* (COMPX);

- the "launched innovation" is described by its *commercial objective* (DYN) and the *time lag* between the end of the collaboration and the launch of the innovation (DELAI).

The dependence links between the different variables have been tested through a regular Chi-2 test at a 10% level of confidence (see Table 2). These links can be mapped (see Figure 1) in a single chart. A couple of remarkable patterns emerge from this representation, and five "associations" particularly catch the attention as they suggest strong links between the concerned variables. All five associations display stable configurations[5]. Without discussing the details of the findings, the main conclusions that emerge from each pattern will be presented.

1. SIZ - FONDS - CAi : this pattern suggests a strong relationship between the size of the company, the impact of the R&D collaboration on the firm's competence building and the innovation-induced turnover. The smaller the firm, the stronger these effects appear.

2. SIZ - REL - CAi suggests that the "new partners[6]" of CEA tend to be small companies, and that these collaborations generate relatively important amounts of turnover for the firms concerned.

3. REL - CAi - PERCAi suggests that the collaborations with "new partners" tend to induce relatively important and long-lasting increases in turnover.

4. COMPE - FONDS - EXT suggests the existence of a link between the preexisting skills base of the firm, the competence building through the collaboration, and the diffusion of the new knowledge in the firm. The presence of technical skills appears to be a condition for the building of new competencies and the spreading of the new knowledge in the firm.

5. COMPE - CONFIG - DYN indicate an articulation between the preexisting skills base of the firm, the organizational configuration of the collaboration and the commercial objective that

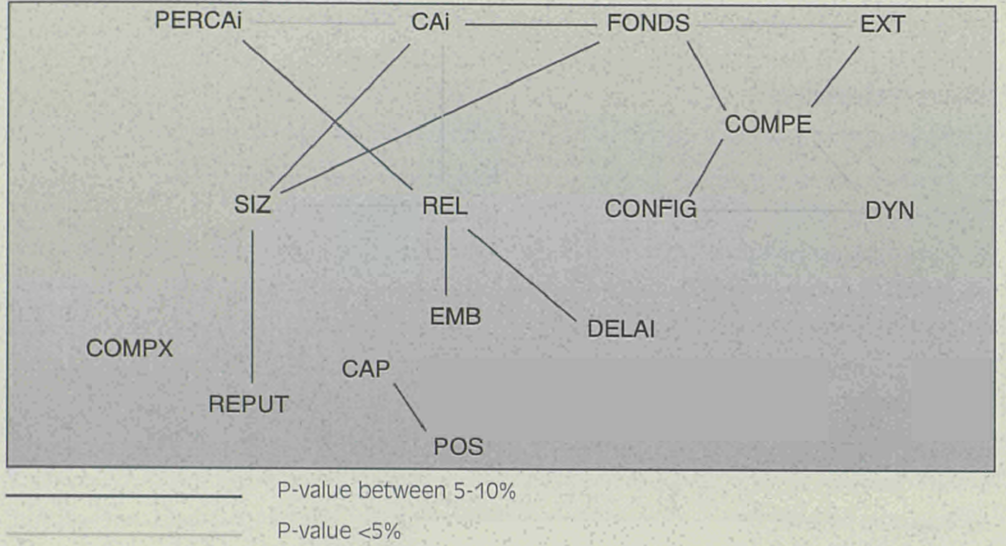
This study is not limited to describing the impacts. Each R&D collaboration in the sample is described through an array of variables that presumably intervene in the generation of these impacts

Table 2. The results of the Chi-2 test

	1. Profile		2. Collaboration				3. Innovation		4. Induced effects						
p-value															
	SIZ	COMPE	COMPX	POS	CONFIG	REL	DYN	DELAI	CAi	PERCAi	EMB	CAP	EXT	FONDS	REPUT
SIZ															
COMPE	66,20%														
COMPX	**3,80%**	95,60%													
POS	37,70%	79,60%	23,10%												
CONFIG	86,00%	**6,30%**	28,50%	60,10%											
REL	**3,90%**	66,70%	30,10%	66,60%	11,70%										
DYN	17,60%	**3,50%**	30,10%	68,00%	**1,20%**	57,40%									
DELAI	45,70%	68,80%	72,50%	45,60%	67,10%	**9,80%**	28,10%								
CAi	**3,90%**	24,60%	21,20%	87,50%	37,90%	**1,80%**	26,90%	29,10%							
PERCAi	58,60%	85,90%	12,40%	65,70%	55,90%	**7,70%**	60,30%	15,30%	**0,00%**						
EMB	11,40%	20,80%	39,10%	**0,30%**	18,40%	**8,20%**	23,00%	22,40%	24,90%	64,40%					
CAP	**3,00%**	29,50%	15,10%	**8,80%**	60,30%	13,10%	43,10%	87,10%	31,60%	68,80%	26,60%				
EXT	31,00%	**6,10%**	21,10%	85,70%	53,60%	17,70%	72,90%	72,50%	21,50%	88,50%	87,60%	45,70%			
FONDS	**8,40%**	**5,50%**	45,20%	78,60%	84,80%	35,30%	72,10%	28,20%	**9,60%**	87,00%	35,40%	30,00%	**1,00%**		
REPUT	**6,50%**	48,20%	79,30%	27,70%	35,10%	46,60%	64,60%	46,20%	14,40%	24,30%	78,30%	17,30%	79,30%	26,20%	

All the variables have been tested by pairs. Among the 106 relationships that have been tested, 20 are relations of dependence at a level of confidence of 10. These are the dark squares in the chart. It appears that all variables of a same "block" are independent of each other , i.e. there is no redundant information in the variables of the "block".

Figure 1. Synopsis of the relationships between dependent variables



SIZ, COMPE = Firm profile
CONFIG, POS, COMPX, REL = Collaboration
DYN, DELAI = Innovation
CAi, PERCAi, EMB, CAP, EXT, FONDS, REPUT = Induced effects

drives the innovation project. Three scenarios can be identified:

- firms with preexisting (technological and commercial) capabilities tend to get involved in intense cooperation schemes that allow them to be constantly connected with the latest technological developments in order to remain on the leading edge of their market;
- firms with a set of relevant technological capabilities tend to link up with a complementary capability set in order to share the risks of diversification;
- firms with commercial opportunities in their existing business tend to externalize the developments that allow them to take a competitive leap.

Conclusions

The results suggest that the impact variables do not depend on the "innovation" variables and the only variables that intervene directly in the impact generation process are SIZ, COMPE, REL. This suggests that it may be possible for project leaders in public laboratories to influence the industrial impact generation process by choosing the "right" partner. Indeed, small companies (less than 100 people) seem to be particularly able to benefit from R&D collaborations in commercial terms. And the presence -in the partner firm- of a relevant technological background intervenes as leverage in the use and dissemination of new technological knowledge.

Two lessons can be learned from these results:
1. The underlying analysis supports the hypothesis that technology encompasses immaterial dimensions and indicators have been developed that account for the impacts generated by the latter.

2. Independently of the contingencies that might blur the evidence, one finds that the public R&D programme administrators can generate impacts for collaborating firms, impacts which are not merely a matter of chance: there is some scope for intervention and this research project has tried to identify the structural conditions.

The results of the analysis suggest that it is possible for project leaders in public laboratories to influence the industrial impact generation process by choosing the "right" partner

Keywords
public research laboratories, evaluation, technology, R&D collaborations, market impact

Notes/References

1- CEA evaluates the market impact of its R&D collaborations by the innovation-induced turnover that the industrial partner generates on the basis of the newly acquired technological knowledge.

2- Generally qualitative appraisals on Likert-scales, or free text appraisals.

3- "Naturalistic generalization" is arrived at by "recognizing the similarities of objects and issues in and out of context and by sensing the natural co variations of happenings".

4- Stake (1978), p.6, in : Shadish, W.R. Jr., Cook, T.D., and Leviton, L.C., (1991) *Foundations of Program Evaluation, Theories of Practice*, Newbury Park, CA : Sage Publications.

5- The stability of the triangular relations has been tested through the introduction of a variable that depends on one of the associated variables. The results can be provided by the authors upon request.

6- "New partners" are those whose links with the CEA are closely connected to a special technological development, whereas the "usual partners" are those companies the CEA has been involved with throughout the nuclear mission.

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