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All four chapters in this part are concerned with models of the performance of scientific research under various institutional and funding arrangements. Although the questions asked and answered may arise in any economy where the allocation of resources for scientific research is of policy concern, they are particularly important and relevant for those concerned with the design and evolution of a European Research Area (ERA). Such a change in the organization of research brings together basic research that was formerly conducted primarily at the national level and changes the incentives for and organizational structure of the performance of such research. The associated institution-building provides an opportunity to reconsider and re-evaluate the choice and extent of public funding mechanisms.

Economic policy in this area proceeds from a premise that there is a role for government in the provision of funds for scientific research due to the large externalities that such research generates and the difficulty and cost of assembling its beneficiaries into an institution that will provide funding for the research. As was pointed out by Nelson (1959) long ago, the closer research is to basic science and the more diffuse its applications, the greater the argument that the benefits to such research are so diffuse and the beneficiaries so uncertain that funding for it is best provided by a governmental or quasi-governmental entity.

Once we accept this basic premise, several policy questions arise:

1. How much funding should be allocated for basic and scientific research?
2. In what areas? How should projects be chosen for funding?
3. How should we organize the research, especially given its cumulative, interactive and dynamic nature?
4. In making these decisions, how can we ensure that the promised benefits to society from enhanced knowledge are achieved? That is, how can we ensure that spillovers actually take place?

When trying to answer the questions posed above, the researcher confronts the issue of deciding which objectives he or she should try to achieve: what things should be included in the social welfare function.

1. Should he or she maximize knowledge or minimize the variance in access to that knowledge? If so, what is the metric for knowledge?
2. Should the focus perhaps be more directly on quantities subject to economic measurement such as growth or output? If so, how does the distribution of knowledge resources affect growth?



3. What about other goals such as distributional equity or 'social cohesion'? How should they be incorporated? Are they necessarily in conflict with the other goals?

The chapters in this part focus primarily on the third question (the organization of research) posed above, exploring a variety of mechanisms and using a range of methodologies, from game theory to simulation to more qualitative analysis. In evaluating research funding policy, they focus to a great extent on the intermediate output – knowledge – while paying some attention to its distribution, taking the positive effects of this output on growth as given.

Clearly spillover benefits vary enormously across different types of research. Some types of research are not directed towards any particular commercial goal and therefore one might expect the benefits to be rather diffuse. Such research is best funded by government because no individual firm would be able to appropriate enough return from it to pay for undertaking the research in the first place. Other types of research generate results that are only suitable for use in a single industry (for example, the technical development of semiconductor manufacturing equipment or improved electric utility generation equipment). Such research may be best funded by industry consortia, as suggested by Foray (Chapter 11), because such consortia internalize both the costs and all the benefits.

Several of the chapters in this volume do an excellent job of highlighting the trade-offs inherent in the public funding of research: as in any economic system, when there is heterogeneity in initial endowments, the efficient allocation of resources does not necessarily have good distributional properties. In the case of the allocation of resources for knowledge creation, the fact that the production of knowledge has increasing returns properties means that using efficiency as the only criterion may serve to exacerbate differences between and among different geographical regions and research networks. In fact, at some level, the justification for creating an ERA must certainly be accessing the increasing returns available with increasing specialization at larger scales. Exploring the trade-off between this goal and the desire to enhance research productivity in disadvantaged regions and institutions is an important consideration in the David and Keely (Chapter 8) and Cowan and Jonard (Chapter 9) chapters.

However, the research presented in this part occasionally ignores or downplays another important consideration in the design of public policy in this area: the method by which research is funded will often have an impact on the amount and type of research chosen via the incentives created by the funding mechanism. This is because of the fixed cost nature of the research production function, which implies that private incentives to perform research can be increased by granting exclusive property rights to the output or by encouraging the internalization of spillovers via alliances or industry associations. Thus a direct consequence of the attempt to correct the underprovision of basic or generic research can often be to create another drag on social welfare in the form of the monopoly pricing of output. See, for example, Grindley et al. (1994) on the US experience with SEMATECH. The message is that ensuring funding by internalizing the benefits to the research via industry consortia or the patent system may carry with it the cost that these mechanisms facilitate the creation of barriers to entry and monopsonistic behaviour towards suppliers.

The chapters divide naturally into two groups: (i) David and Keely on the interaction of research network funding at different jurisdictional levels and Cowan and Jonard on the performance of research network funding in the presence of scientific researcher mobility; and (ii) Swann (Chapter 10) on the trade-off between club and public provision of goods with positive externalities and Foray (Chapter 11) on the industry-specific club for funding research as a policy experiment. Chapters 8 and 9 are concerned specifically with the trade-offs and complications that arise in structuring funding allocation mechanisms for basic scientific research, using simulation models to explore a number of scenarios, whereas Chapters 10 and 11 are more concerned with the issue of when and where the public funding model is appropriate and only secondarily with the details of its implementation.

**Funding Scientific Research**

Cowan and Jonard develop a complex simulation model of an open science network with spillovers in order to explore the influence of job market flexibility for scientists, the frequency of job changes and the strength of network connections on the following:

1. total knowledge;
2. heterogeneity across departments in knowledge levels; and
3. specialization across departments/groups.

They find that job market flexibility (the ease with which moves take place and the frequency with which the market opens) increases total knowledge generation slightly and leads to less specialization across departments. The latter outcome is consistent with observations on differences between Europe and the United States.

It should be noted that their model is primarily about non-codified knowledge spillovers and not about the spread of codified knowledge via journal publication. It also ignores the rather important role of teaching and graduate student mobility after training. Nevertheless, properly calibrated, the model should prove useful for analysing the productivity of one aspect of differing innovation systems while being able to hold all other features of the system constant.



David and Keely break new ground in the policy analysis of the 'allocation of resources for invention' by explicitly considering the interaction between two funding agencies with (potentially) different goals. They are concerned with two questions, the second of which follows from the first:

1. What is the equilibrium funding and knowledge 'reputation' in a multiplayer game involving researchers, national funding agencies and a supra-national funding agency that awards grants only to collaborations?
2. Given the endogenous response by researchers, how should the two types of agencies achieve their goals where the goals are defined as:
   a. raising the average 'reputation' level; and
   b. lowering the variance in 'reputation'.

The model they use delivers two rather interesting and somewhat provocative results: first, that the supra-national funding agency should fund collaborations with the highest internal diversity in research reputation and, second, that the national funding agencies should not condition their funding on the decisions of the European Commission. In drawing these conclusions, they allow the agencies to have as a goal either raising the average level or lowering the variance. They also find that where the agencies choose different goals, the supra-national agency will not be able to achieve its optimum.

A natural question is whether the set of goals considered is the right set if the ultimate aim is to optimize the contribution of knowledge to economic growth. Several things might suggest that they are not: first, it is not clear what the relationship is between research 'reputation' and research productivity, although presumably they are correlated. Second, and more seriously, minimizing variance while ignoring the average level of reputation may yield a rather poor outcome under some conditions, especially if the knowledge base depends not on some integral over the distribution, but merely on the position of the upper tail. That is, if all worthwhile discoveries come from research groups with very high reputations, minimizing variance may be exactly the wrong thing to do. On the other hand, objective functions of this type may facilitate the diffusion of new discoveries across the region via the learning that takes place.

## 2 Funding Applied Industrial Research

Swann and Foray tackle a different problem: the provision of industry-specific public goods. Numerous examples of the voluntary formation of research organizations designed to internalize spillovers within an industry exist, although many of the most visible examples are essentially government mandated or instigated, such as SEMATECH in the United States, joint research organizations run by the Ministry of International Trade and Industry (MITI) in Japan or the Electrics and Telecommunications Research Institute (ETRI) in Taiwan. Foray reconsiders the interesting suggestion put forth by Romer (1993) for industry R&D boards and argues for their use at least in an experimental way.

The chapter by Peter Swann addresses the question of when basic research should be provided as a 'club' good paid for by members (of which one example might be an industry R&D board) and when it should be publicly provided. The criterion he uses is the maximization of social economic welfare and he is careful to draw out the distributional consequences of the various types of funding, as well as explicitly considering the transaction costs associated with each. As suggested earlier, the choice of club versus public funding is not a simple one, because the formation of a private organization to fund research may change the allocation of the benefits of that research from external to internal, to the extent that a club is able to internalize and transfer returns to itself via pricing behaviour. That is, at a given level of welfare benefits from innovation, the partition between external and internal benefits of that innovation depends on market structure.

Although the industry-specific funding mechanism for certain types of basic and applied research has considerable appeal, it is fraught with problems in practice. First there is the question of the definition of the industry: all firms within an industry are taxed to support the research and presumably can benefit from it. New entrants will be problematic: either they will be disadvantaged (because they are not members) or they will free ride on existing research, depending on the exact nature of the intellectual property regime and its effectiveness. Existing members of the consortium may be able to direct research towards avenues that ensure barriers to entry for new firms.

A second problem is the one identified so well by Swann in his model of the diffusion of new ideas and discoveries: identification *ex ante* of the type of diffusion likely to occur and the firms that will benefit is very difficult in many cases, but essential if the likely participants in such a club are all to be taxed. This is not to deny that such clubs may not form voluntarily if allowed to, as witness the recent rapid increase in research joint venturing, both within countries and internationally (Hagedoorn and van Kranenburg 2001). But such organizations are usually relatively small and exclude many others in an industry.



Finally there is the issue of appropriability and intellectual property (IP). From the perspective of a firm considering entering into an R&D cooperation arrangement, the trade-off is between benefiting from others' R&D (a 'good') while not spilling over too much of one's own (a 'bad'). There is considerable anecdotal and survey evidence that IP issues are the most contested area in negotiating R&D cooperation agreements. Using data on Belgian firms, Cassiman and Veugelers (1999) highlight the empirical importance of appropriability in determining who enters voluntarily into R&D cooperation, and the connection between this and the spillovers actually achieved. Branstetter and Sakakibara (2002) find that Japanese research consortia have relatively better outcomes for basic research (which presumably generates more spillovers) and worse outcomes when the firms compete in the product market.

In spite of these reservations, there is reason to believe that where beneficiaries can be identified as belonging to a particular industry, and especially where standards are important, so that a single technology trajectory is the preferred one, such industry-specific funding mechanisms might be a policy option, at least on an experimental basis. However, further consideration of the ideal IP ownership structure in such an arrangement might be in order.

# NOTE

* The author acknowledges 'Technological knowledge and localized learning: what perspectives for a European policy?', a project funded through research contract No. HPSE-CT2001-00051 under the European Directorate for Research within the context of the Key Action 'Improving the socio-economic knowledge base'. Thanks are due to Aldo Geuna and Pier Paolo Patrucco for their comments on preliminary versions of this commentary and to Jean Luc Gaffard and Michel Quéré for their comments after its presentation at the Institut de Droit et d'Économie de la Firme et de l'Industrie (IDEFI) workshop 'Innovation and growth: new challenges for the regions' at Sophia-Antipolis, 18–20 January 2002. This commentary also benefited from the stimulation and the discussion following the presentations of Paul David, Peter Swann and Robin Cowan at the NPRnet meeting at the École des Mines, Paris, 3–4 May 2001.

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