Technology Analysis & Strategic Management, Vol. 15, No. 2, 2003

Carfax Publishing
Taylor & Francis Group

The Evaluation of Strategic Research Partnerships

STEPHEN MARTIN

ABSTRACT *Policy implications of strategic research alliances are analyzed, with emphasis on government-private sector cooperation, government support for private sector innovation, and evaluation of such government programs.*

> Results? Why, man, I have gotten a lot of results. I know several thousand things that won't work. THOMAS EDISON

1. Introduction

A strategic alliance[1] 'enables a firm to focus resources on its core skills and competencies while acquiring other components or capabilities it lacks from the marketplace'. Such alliances extend beyond research, the focus of this paper, and take a variety of forms. My own preference is for the 'operating entity' and 'secretariat' classification of Ouchi[2] and Vonortas,[3] which at least have the merit of being based on functional differences. An operating entity alliance or joint venture involves creation of an alliance-specific laboratory or other research establishment, while a secretariat alliance implies the circulation among partners of results obtained at partners' research operations.

It is sometimes said that theoretical research in economics is a largely self-contained activity, firmly insulated from the vagaries of evidence about the subjects it analyzes.[4] The extent to which this might be true in general is beyond the scope of this paper, but it does seem to be an accurate description of a good deal of the recent theoretical literature on R&D cooperation. What is even more discouraging, however, is that much of the policy literature on R&D cooperation seems disconnected from both mainstream theoretical[5] and empirical work on the phenomenon.

In Section 2, I review the literature on R&D cooperation. Section 3 takes a closer look at the pharmaceutical sector, while Section 4 turns to evaluation of public sector R&D and public-private sector cooperation, while Section 5 considers measuring the returns to public support for private R&D. Section 6 looks at private returns to R&D. Section 7 comments briefly on insights from industrial economics for evaluating the returns to R&D and Section 8 presents a summary of alternative measures of research alliance performance.

2. The Literature

Much of the theoretical work on R&D cooperation in the 1990s took off from the seminal work of d'Aspremont and Jacquemin (henceforth, AJ).[6] The impact of this intentionally

Stephen Martin is at the Department of Economics, Krannert School of Management, Purdue University, West Lafayette, Indiana 47907–1310, USA (E-mail: smartin@mgmt.purdue.edu).

I am grateful for the comments of an anonymous referee. Responsibility for errors is my own.

ISSN 0953-7325 print; 1465-3990 online/03/020159-18
DOI: 10.1080/0953732032000051082

simple model[7] may well have surprised even the authors, who referred to it as 'an example'. In its basic form, it considers a duopoly market. Since there are only two firms, R&D cooperation, if it occurs at all, includes all firms in the industry. This is in sharp contrast to the kind of R&D cooperation described by, for example, Hagedoorn and Schakenraad,[8] who document that major players in innovation-intensive industries simultaneously undertake a great many cooperative R&D projects, often with narrowly defined targets.

In the AJ model, innovation is deterministic: firms select a certain cost reduction that they will pay for, and they obtain that cost reduction with certainty. Since innovation is deterministic, if a firm undertakes R&D at all, it performs only one R&D project. A deterministic formulation abstracts from the uncertainty that is inherent in innovation. It is not obvious why the deterministic formulation is preferred in the literature, since racing models allow for uncertainty and are not technically more difficult than deterministic models.[9]

In the AJ model, if a firm performs R&D, it is R&D output—a cost reduction—that spills over to the other firm. This spillover just happens: if firm 1 pays for (and therefore obtains, given the deterministic nature of the model) a unit cost reduction x_1, firm 2's unit cost falls by sx_1, where the spillover parameter s lies between zero and one.[10]

The d'Aspremont and Jacquemin model is unstable for large spillover levels (exactly when the impact of cooperative R&D on dynamic market performance is of greatest interest). Instability does not arise in the model of Kamien *et al.* (henceforth, KMZ),[11] who consider R&D input spillovers rather than R&D output spillovers. The two models are compared by Amir,[12] who shows that

- the two models are not equivalent,
- that the AJ systematically predicts higher levels of R&D than the KMZ model, and
- that the KMZ model predicts that industry R&D levels decline as (input) spillovers rise, while the AJ model makes the same prediction only for lower values of the (output) spillover rate.

Amir argues that the KMZ model is better suited for the analysis of independent and cooperative R&D. He distinguishes seven R&D cooperation scenarios from the theoretical literature:[13]

(1) Case N: firms behave noncooperatively in both R&D and the product market;
(2) Case C: firms select equal R&D levels for their individual R&D projects to maximize joint profit, behaving noncooperatively on the product market;
(3) Case CJ: as in case C, setting the R&D spillover equal to 1.
(4) Case NJ: case N, with the spillover parameter set equal to 1 (this seems to be the case of a secretariat joint venture);
(5) Case J: the firms set up one laboratory, share the cost, and both enjoy the same cost reduction (this is an operating entity joint venture);
(6) Case CC: firms collude at both levels, carrying out independent R&D with the natural level of spillovers.

Specifications in which cooperating firms set the spillover parameter equal to 1 are considered by KMZ. While it may be that firms can increase[14] their knowledge spillover rate, it is by no means certain that they choose to do so, and there is case study evidence that firms do not behave in this way.[15] At least, it would seem preferable to model the choice of spillover rate, rather than simply assume that it becomes 1 for some cases of R&D cooperation.

Much of the theoretical (and policy) literature takes off from the idea that imperfect appropriability is a source of innovation failure in market economies,[16] often appealing to Arrow's frequently quoted observation that[17]

> no amount of legal protection can make a thoroughly appropriable commodity of something so intangible as information. The very use of the information in any productive way is bound to reveal it, at least in part. Mobility of personnel among firms provides a way of spreading information. Legally imposed property rights can provide only a partial barrier, since there are obviously enormous difficulties in defining in any sharp way an item of information and differentiating it from similar sounding items.

Even on a theoretical level, this view has been challenged. Cohen and Levinthal emphasize that information often does not flow freely from innovator to other users:[18]

> we argue that while R&D obviously generates innovations, it also develops the firm's ability to identify, assimilate, and exploit knowledge from the environment—what we call a firm's 'learning' or 'absorptive' capacity. While encompassing a firm's ability to imitate new process or product innovations, absorptive capacity also includes the firm's ability to exploit outside knowledge of a more intermediate sort, such as basic research findings that provide the basis for subsequent applied research and development.

On an empirical level, Levin *et al.*[19] present survey evidence suggesting that innovating firms have many strategies available to exploit their innovations, if not uniquely over all time, at least in advance of followers, allowing realization of first-mover advantages.

A frequent justification for promoting R&D cooperation is that it eliminates 'wasteful duplication'. This justification should by now be thoroughly discredited. It fails both theoretically[20] and empirically:[21]

> From a social point of view, effective pursuit of technological advance seems to call for the exploration of a wide variety of alternatives and the selective screening of these after their characteristics have been better revealed—a process that seems wasteful with the wonderful vision of hindsight.

When the outcome of R&D projects is uncertain, as it always is, it is socially beneficial, and frequently privately beneficial as well, to pursue multiple research paths toward a common target.

In the policy literature Teece[22] and others have emphasized the tacit nature of some kinds of knowledge—in sectors where technology transfer is difficult without the transfer of particular individuals—as a justification for R&D cooperation. It may be so in some sectors: but if knowledge does not flow freely because of its tacit nature, then it cannot also be that firms cannot realize the commercial benefits that flow from their innovations because the underlying knowledge spills freely over outside the firm.

One of the motivations often cited for the US National Cooperative Research Act of 1984 is that it served to reduce business-sector anxiety about possible antitrust liabilities incurred because of participation in R&D joint ventures. It is difficult to know upon what such anxiety might have based.[23] The European Union has always had a positive attitude toward R&D cooperation.[24] US antitrust, to the best of my knowledge, records one antitrust case involving an R&D joint venture.[25] The government's theory in that case was that auto makers had used an R&D joint venture to delay the development of environmentally motivated emission control equipment. The case was settled by a consent decree.

Keeping these characteristics of the theoretical and policy literatures in mind, I have preferred to examine selected portions of the empirical literature for regularities that might appear and offer some insight into possibilities for measuring the impact of public support on technological performance. I have focused in particular on studies of the pharmaceutical sector and of government support for or collaboration with private sector innovation.

3. Pharmaceuticals

3.1. Size Advantages, Absorptive Capacity

The pharmaceutical industry was early on and remains (now along with the more broadly defined biotechnology sector) a proving ground for the study of innovation. In part, the pharmaceutical sector attracts attention simply because of its high policy profile. In part, it attracts attention because it seems apparent that static and dynamic performance in the industry is directly affected by government policy (although opinions differ about the nature of the effects). More recently, the industry has attracted academic attention because it seems to offer a close real-world counterpart to widely used racing models of innovation.

The evolution of the US pharmaceutical industry was shaped by two early policy developments. The 1939 US Food, Drug, and Cosmetic Act separated the purchase decision from consumption for prescription drugs.[26] Consumption could take place only by prescription; the physicians who issued prescriptions did not pay for the drugs they prescribed. The result was to make the demand for prescription drugs price inelastic. Further, pharmaceutical industry researchers in the 1940s developed systematic techniques for identifying antibiotics in soil samples. US patent law was interpreted so that such antibiotics were patentable. This interpretation was by no means inevitable; antibiotics might have been found to be natural substances and not patentable.[27] As a consequence economic profits were diverted into rent-seeking activities:[28]

> New technological opportunities led to patent monopolies. FDA regulations reduced the elasticity of demand. Maximization of monopoly profits with very inelastic demand led to monopoly production rather than to patent licensing. The presence of shared patents and competing patents on similar drugs led to vertical integration, larger firms, and increased advertising in the pursuit of larger market shares in the markets for similar drugs. The increased advertising and R&D stimulated by this competition reduced the profits of the newly integrated firms, albeit not to the competitive level.

It has long been recognized that the pharmaceutical sector is one where patents are relatively effective in securing property rights in innovations. Temin's analysis suggests that effective patent protection did not result in good overall market performance in the US pharmaceutical industry of the 1950s and early 1960s. Drug companies had the option of licensing products in which they had effective property rights, but opted instead to restrict output and dissipate the accompanying economic profits on marketing efforts aimed at physician-prescribers.

Temin finds no evidence of economies of scale in production: leading pharmaceutical firms grew by increasing the number of establishments they managed, but the size of the typical establishment did not increase. On the same point, Comanor[29] finds empirical studies inconclusive, some suggesting the presence of economies of scale, others not. One explanation suggested by Comanor is[30] 'that larger firms are relatively more important when all new drugs are included but not so in regard to the most important innovations'.

Graves and Langowitz[31] analyze the probability of introducing a new chemical entity for a sample of 16 large pharmaceutical firms over the period 1969–1987. They find the elasticity of the expected number of patents with respect to R&D spending to be less than one and to fall as R&D spending rises, evidence for diseconomies of scale in innovation.

Caves *et al.*[32] document that patent protection is not the only device that allows innovating drug firms to collect economic rents. They study 30 drugs that lost patent protection in the decade 1976–1987 and find that after patent protection expires generic substitutes sell at substantially lower prices than the formerly protected version, but that the first variety suffers only modest reductions in market share.[33] Advertising to prescribing physicians—an activity that is cut back in advance of the expiration of patent protection—apparently creates product differentiation that survives well after the introduction of generic substitutes.

Scherer[34] discusses the US Orphan Drug Act of 1983, which gives exclusive marketing rights and tax benefits for firms developing drugs targeting diseases that affect relatively small numbers of people, which Scherer describes as having had 'a marked impact'. This is noteworthy because it suggests the ability of narrowly targeted measures to promote particular policy goals.[35]

DeBackere and Clarysse[36] study a sample of 118 US biotechnology firms over the period 1982–1994. They find that patent probability rises with the number of years a firm has been involved in collaborative research, suggesting that collaborative R&D enhances R&D productivity. Cockburn and Henderson study research programs of 10 pharmaceutical firms in 38 research areas. They find substantial evidence of knowledge flows across firms:[37]

> Some firms pursue different goals within the same general therapeutic area, while others compete more directly. In either case publication and the norms of professional disclosure appear to ensure the rapid exchange of knowledge across the industry. . . . Competing projects are better described as complements rather than substitutes, and there are significant spillovers of knowledge across firms.

They identify three possible sources of large size in research and development, that[38]

(1) larger firms are able to spread fixed cost of research over a larger sales base;
(2) large firms may have advantages in financial markets
(3) larger firms may be better able to exploit economies of scale and scope in the research itself.

A fourth benefit of large size, widely noted in the literature, might be termed the serendipity effect, and is associated with diversification as much as with large size alone: a large, diversified firm is more likely to be able to exploit an unexpected discovery.

Henderson and Cockburn find some evidence that economies of scale in pharmaceutical research increased in importance in the period after that covered by Temin,[39] but also that such economies of scale may have disappeared after 1978. They do find that larger firms enjoy greater R&D productivity than smaller firms, and attribute this to economies of scope—knowledge spillovers across research programs within a firm and the accompanying ability to make productive use of knowledge spillovers across firms:[40]

> the benefits of spillover can be realized only be incurring the costs of maintaining absorptive capacity, which take the form here of large numbers of small and apparently unproductive programs. We believe that these effects are what account

> for the presence of very large research oriented firms, despite sharply decreasing marginal returns to research spending at the level of the individual research program.

Cockburn and Henderson highlight even more strongly the importance of absorptive capacity for dynamic market performance:[41]

> Our results are consistent with the hypothesis that the ability to take advantage of knowledge generated in the public sector requires investment in a complex set of activities that taken together change the nature of private sector research. In the second place, they raise the possibility that the ways in which public research is conducted may be as important as the level of public funding. To the extent that efforts to realize a direct return on public investment in research lead to a weakening of the culture and incentives of 'open science', our results are consistent with the hypothesis that the productivity of the whole system of biomedical research may suffer.

To the extent that strategic alliances add to or maintain absorptive capacity, they have a positive social benefit that is unlikely to be recognized by conventional evaluation methods.

3.2. Organizational Factors

Pisano[42] studied the organizational form of 195 biotechnology sector collaborations involving private firms. His analysis suggests that firms favored equity holdings over contracts as an organizational framework for R&D collaboration. He interprets these findings from a transaction cost perspective: equity holdings raise the cost of opportunistic behavior (which would reduce the value of the equity holding), and representation on the board of directors of the collaborative entity is a vehicle for continuous monitoring of performance.

He suggests[43] that antitrust treatment of R&D collaboration organized by means of equity holdings should balance these efficiency advantages against the possibility that an R&D joint venture might facilitate tacit collusion and worsen static market performance.[44] Pisano[45] notes that much (at least, much early) collaborative biotechnology R&D has been vertical in nature, involving on the one hand small specialized firms in a position to offer specific expertise and skills and on the other large established firms able to offer financial backing and access to distribution channels.

Taking these two contributions together, to the extent that R&D collaboration is vertical in nature, the potential for worsening static market performance is lower[46] than would be the case for horizontal R&D collaboration (that is, among firms operating in the same product market).

Pisano[47] also notes a more recent tendency for established firms to integrate backward into R&D activity and for specialized biotechnology firms to integrate forward into production and distribution. Such integration, increasing the number of actual and potential competitors, improves static market performance. On the one hand, this finding suggests that public support for biotechnology sector innovation should be structured in a way that does not raise the cost of entering the market. More generally, it suggests that the way public support for biotechnology innovation is structured should not take for granted that observed private-sector relationships are fated to continue: the kinds of contracts that are privately optimal in one phase of an industry's life cycle may change over time, as indeed may the implied equilibrium market structure.

Lerner and Merges[48] analyze the allocation of control in vertical biotechnology alliances. They find that the greater the financial resources of the specialized biotechnology firm, the less the degree of control allocated to the larger (typically a pharmaceutical) firm.[49]

Public policy affects equilibrium market structure and therefore equilibrium market performance. Any program of public support will alter the balance of bargaining power between biotechnology firms and larger partners. Programs of public support that increase the financial resources of specialized biotechnology firms are likely to increase the bargaining power of those specialized firms with respect to established pharmaceutical firms, reduce entry costs and improve static as well as dynamic market performance.

Tapon and Cadsby[50] analyze private sector-university pharmaceutical collaboration. Their discussion, like the work of Cockburn and Henderson, suggests the positive impact of knowledge spillovers on innovation. Tapon and Cadsby argue that private pharmaceutical firms link up with university laboratories to promote basic research and as a way of tapping into specialized stores of knowledge in areas that developments in the field reveal to be important.

Quoting a biotechnology researcher, they document the inherently uncertain nature of biotechnology innovation:[51]

> I think that rational drug design is obviously very admirable. It is more than a great idea, it is a move in the right direction. It applies as much rationality to your programs as possible. But, you're not going to be able to predict 100% ... of the outcome. You're always going to have things that happen that nobody really foresaw and you look back in hindsight and say that there is no way that we could have predicted that outcome.... There is a certain amount of good luck involved ... you have to have the breaks; if you don't have the breaks in drug development you may have great difficulty in getting any compound.

Tapon and Cadsby also find that physical proximity of research facilities has a positive impact on research productivity.[52]

3.3. Implications for Evaluation

The importance of knowledge spillovers in the pharmaceutical sector means that the benefits of obtaining innovative results extend beyond the particular program that produces those results. Even a very precise measurement of the output of a particular pharmaceutical research program will provide only a lower bound measurement of the welfare impact of that output from a social point of view.

More generally, these results suggest that—certainly in the pharmaceutical sector, and perhaps elsewhere in the economy as well—that public support for private innovation should be carried out in a way that promotes the free flow of knowledge among R&D-active firms. A performance-enhancing *quid pro quo* for public support of private R&D is that patents obtained with such support should be openly licensed on reasonable terms by the private-sector firm that holds the patent.[53]

The inherent uncertainty of R&D outcomes in this area also signals difficulties for evaluation. Results must be assessed *ex post*, but any cost-benefit analysis must include the cost of programs that were reasonable *ex ante* but happened, by the luck of the draw, not to mature as rapidly or in the directions expected. Evaluation should not be carried out at too disaggregated a level.

4. Government R&D, Government-Private R&D Cooperation

Joly and Mangematin[54] study 20 French public laboratories associated with the National Institute for Agronomic Research (INRA). They confine their analysis to two research departments, but even working with this limited sample they distinguish three types of public laboratories:

(1) Research centres for the profession: laboratories with close ties to small- and medium-sized firms and industry associations, concentrating on the development of improved strains of plants;
(2) Designers of generic tools and methods: laboratories concentrating on basic research;
(3) Basic and specialized laboratories: provide expertise to industry to solve specific problems.

While some of their conclusions may be specific to agronomics and to the French institutional setting, the point that public laboratories are heterogeneous in terms of assets, expertise and activities seems likely to be quite general. Further, the finding that some public laboratories apply specialized expertise to some specific, long-term problems for industry may well be a leading indicator of the role that will be played by (former) US defense laboratories.

This conclusion is consistent with that of Nelson,[55] who emphasizes the importance of the presence or absence of a government procurement interest in designing a program of public support for private innovation.

In the same vein, Ham and Mowery,[56] who present five case studies of Cooperative Research and Development Contracts (CRADAs) between private firms and the Lawrence Livermore National Laboratory, conclude that the most successful joint efforts are those that 'draw on the historic missions and capabilities of the laboratories' and that 'defense laboratories are poorly suited to that task of civilian technology development in areas not directly linked to their historic missions'.[57] They also highlight the importance of the 'generic' benefits derived by private firms from Cooperative R&D Agreements with Lawrence Livermore National Laboratory:[58] 'design principles, engineering techniques, testing methods' (surely, a kind of spillover contributing to absorptive capacity). What private firms pay under such contracts, and the value of the inputs they commit, may be one measure of what they expect the output to be worth, but to the extent that the benefits are generic, it will be a lower bound of the social benefit.

Another noteworthy result of the Joly and Mangematin study appears in their account[59] of interviews with the director of research at INRA, who expressed disappointment with his experience that the information flows in public-private contracts were all one way, from the public to the private sector. They comment that this 'shows that co-operative research is not synonymous with a process of combined learning'. It is common in theoretical models to assume the innovation spillovers are complete within R&D joint ventures, and this interview evidence suggests that other specifications may be worthy of exploration.

Jaffe *et al.*[60] examine patenting practices of US Federal laboratories, and patenting and citation practices of the NASA-Lewis Research Center. Although they interpret their findings as confirming that patent citations are a valid index of the importance of the innovation covered by the cited patent, they also find that[61] 'approximately one-fifth … of citations are cases where neither the technology nor the application is clearly related to the cited patent … apparently spurious citations' and that[62] 'citations are clearly a noisy indicator of spillovers'. The conclusion that counts of the number of patent citations are a valid but noisy indicator—whether of importance of the innovation cited or of spillovers—is not necessarily comforting from the point of view of using patent citations to evaluate the impact of a program to support innovation.

Leyden and Link[63] discuss the empirical regularity that cooperative R&D projects that include public laboratories tend to be larger, all else equal, than those that do not.

They point out that public laboratory participation in a joint R&D project most likely reduces the ability of private participants to appropriate profits flowing from successful innovation[64] but may also reduce the cost (to private participants) of monitoring the R&D efforts of participating firms. If a joint R&D effort includes a large number of partners, any incremental reduction in appropriability is likely to be small, while the reduction monitoring costs remains as a private benefit to the participating firms. To the extent that such a reduction in monitoring cost enables joint R&D that would not otherwise take place, or makes such joint R&D as does take place more effective, there is a public benefit as well. The social benefit due to this type of reduction in transaction cost is unlikely to be caught by traditional measures of innovative output.

5. Government Support for Private R&D

Lichtenberg[65] criticizes econometric studies of the impact of direct Federal funding of R&D on private R&D spending that ignore differences in the composition of demand across industries. Since much private-sector R&D spending is aimed at satisfying government demand, industries that benefit from substantial government demand will conduct substantial R&D to satisfy that demand and also tend to receive greater-than-average government support for R&D. Ignoring demand variations (and simultaneous causality) tends to bias upward the estimated impact of private on public spending.

This point is correct in principle. It is not clear how important it is in practice. Using a sample of Federal Trade Commission line-of-business data, Lunn and Martin[66] find that a greater share of industry sales to the Federal government lowers privately financed R&D spending per dollar of sales, while a greater share of industry sales to state and local governments increases it, all else equal. Both effects are especially pronounced for a subsample of high-technology industries.

Cohen[67] makes a point about the impact of government demand on government-supported R&D that is perhaps more relevant to the question of program evaluation. In sectors where the public sector is a significant consumer, it can virtually guarantee the commercial success of sponsored projects by its purchasing decisions. In such sectors, commercial success is a weak indicator of program effectiveness.

Wallsten[68] looks at another manifestation of simultaneous relationships in this area. He examines the impact of R&D grants made under the US Small Business Innovation Research and emphasizes the importance of taking the incentives of funding agencies into account:[69]

> If government agencies face incentives to fund the most commercially promising proposals they receive, they will be inclined to support projects that would be privately profitable—and thus would be undertaken anyway—rather than projects that would benefit society but are privately unprofitable.

In the event, his results suggest that SBIR grants to publicly-owned recipients crowd out private R&D spending on a one-for-one basis, so that public grants replace private R&D spending but do not increase total R&D spending.[70] The implied risk for evaluation programs that adopt commercial indices of success is that they would create just such an incentive to fund R&D activity that would have been funded in any event.[71]

Fölster[72] analyzes a sample of 540 R&D projects of Swedish firms and their research competitors. His results indicate that R&D subsidy programs that allow firms to choose the form of cooperation do not increase the probability of cooperation, but increase the incentive to invest in R&D. Subsidies that require firms to cooperate and to share results increase the probability that firms will cooperate, but decrease the incentive to invest in R&D.[73]

Rosenfeld[74] reports two case studies of evaluations of US state programs to promote network cooperation among small- and medium-sized enterprises. The evaluation methodology included surveys of participants, interviews, and some analysis of data describing the activities of the firms involved. One of the evaluations included an assessment of cooperation on the local economy. Evaluations of this kind have an unavoidable subjective element.

Luria and Wiarda[75] report on objective evaluation of programs of the Midwest Manufacturing Technology Center. Their description will evoke admiration and give pause to those contemplating similar efforts. It is clear that objective evaluation is time consuming, costly, requires considerable effort, and is likely to be sector-specific, in that indicators of success developed for one industry often will not carry over to another. (Examples that they mention include manufacturing lead time, inventory-sales ratios, and the ontime delivery percentage). They used the offer of benchmarking reports to entice firms that were not recipients of MMTC funding to contribute comparative data to the evaluation process.

Westerback[76] studies the impact of Strategic Information Technology Management practices imposed on Federal agencies by the Clinger-Cohen Act of 1996. As one conclusion of the study, she finds that[77] 'Use performance measures as a proxy for return on investment' is a useful information technology management practice for Federal agencies, but she also writes:[78]

> This is an expedient approach to get around the difficulty or, and lack of consistency in, measuring return on investment in the federal government. Many assumptions and judgments are factored into return on investment figures. The requirement that a project show a positive return on investment may lead to strained use of the numbers.

If it is difficult to measure the return on government practices that are reasonably close parallels to functions performed and evaluated in the private sector, how much more serious will the problem of evaluation be for the federal contribution to strategic alliances? With strategic alliances the assets the federal agency brings to bear are fundamentally different from the kinds of assets found in the private sector (and it is this very difference that makes the alliance worthwhile for the private partner).

6. Private Returns

Boulding and Staelin[79] use the PIMS database[80] to examine the impact of private R&D spending on the private rate return. There are many studies of this kind and they generally find that the impact of private R&D spending on the private rate of return is positive, as do Boulding and Staelin.[81] Such techniques might be applied to study the impact of public funding for cooperative R&D on private returns (seeking to avoid the critique of Lichtenberg[82]). The result would be a lower-bound indication of the social return.

Zahra and Bogner[83] examine the impact of technology strategy on the performance of new firms in the computer software industry. Their measures of performance are the rate of return on stockholders' equity and the growth rates of sales and of market share. All three variables seem to have been afflicted by measurement difficulties.

It might be possible to measure the impact of strategic alliance participation on the rate of return on equity for relatively undiversified firms that participate in at most one strategic alliance at a time. If all private-sector firms allying with a government agency fell in this category, a summary of the effects might serve as an indicator of the value of such collaboration to the private business sector.

Spillovers and externalities limit the use of the rate of growth of sales or of market share as an indication of the social return to innovation. In the presence of R&D spillovers, the slower growth or lost market shares of rival firms must be set against the benefit (more rapid growth, greater market share) received by a cooperating firm.

Chan *et al.*[84] examine the impact of the formation of strategic alliances on movements in the share prices of 460 firms involved in 345 alliances. They do not limit their attention to innovation alliances. They find that strategic alliances increase the combined market value of the firms involved and that for horizontal alliances the increase is larger, all else equal, if it involves knowledge transfers.

While the event study methodology might be applied to evaluate the private returns to specific companies and for specific innovation alliances, it seems unlikely that it could be used to evaluate results of a support program aimed at a wide range of firms, not all of which would be listed on financial markets. The diversified nature of many firms and the large number of strategic alliances in which some are involved might also mute the impact of a particular alliance on firm value.

Yang *et al.*[85] analyze factors determining the performance of NCRA registered joint ventures. They find that performance is enhanced by alliance stability and also if the alliance combines complementary assets. Their performance measure, however, is based on subjective evaluation of the extent to which a joint venture achieved its objectives. They specifically suggest[86] that '[a]chievement of objectives is an appropriate measure of intermediate performance for R&D strategic alliances in cross-sectional studies', but there will be many circumstances in which such a measure could not be constructed even with respect to the private rate of return.

7. Perspectives from Industrial Economics

Industrial economics as a field overwhelmingly employs partial equilibrium analysis. Strategic research alliances surely have some general equilibrium consequences, although it may well be that their primary impacts are confined to particular sectors of the economy.

Keeping the existence of such general equilibrium effects in mind, it seems nonetheless to be the case that just as Nelson wrote[87] 'if they are to be successful, public policies to stimulate technical progress need to be nicely tuned to the particulars of the different economic sectors', so today we can write that if the evaluation of strategic research alliances is to be effective, so evaluation methods need to be tuned to the particulars of different sectors and of the types of alliances.[88]

This observation is consistent with the evolution of empirical research on static market performance in industrial economics, which has passed from reliance on industry cross-section data in the 1960s and 1970s to analysis of time series and panel data at and below the firm level.[89] The purist approach to measuring the impact of strategic alliances on sectorial performance would be to specify and estimate a complete (demand-side and supply-side) structural model, allowing for firm-specific rates of technical progress and allowing those rates to depend on explanatory variables measuring both the firm's own participation in strategic alliances and on the sector-average frequency of strategic alliances.

The data requirements to carry out such a study would be severe.[90] Results would, of course, depend on the specifications used for estimation. That is true for all empirical work. Analysis taking product varieties as given would for the most part apply techniques that have appeared in the literature. Analysis that allowed for new product development—an essential aspect of strategic alliance output in some sectors—would probably require use of techniques only recently developed and not yet widely applied.[91] The results of such a study would give some indication of consumer and net producer benefits from strategic alliances in the sector under investigation. The results would not give an indication of spillovers outside the target sector.

8. Conclusion

There are valid questions about any evaluation scheme.

One relates to interpretation of whatever 'grade' is generated. Low values of a particular performance index may simply reflect the highly skewed distribution of 'big ticket' innovations:[92]

> researchers who seek to assess the success of government technology programs should focus most of their effort on measuring returns from the relatively few projects with clearly superior pay-offs, not on projects in the heavily populated low-value distribution tail.

If major innovations come along only once in a great while, failure to achieve stunning results is not failure.[93]

In such a world, the question the evaluator should seek to answer is not 'Were the results good?' but rather '*Ex ante*, was it reasonable to think that there was a high enough probability that the results would be good to devote resources to the project?' For basic research, at least, *ex post* peer review might answer that question.[94] They can present estimates of just such expected rates of return, based on survey and interview evidence, for a sample of projects subsidized under the US Advanced Technology Program.[95]

There is also the 'spillover problem' of Klette *et al.*:[96]

> if an evaluation study finds little difference between the supported firms and the non-supported firms it could either be because the R&D program was unsuccessful and generated little innovation, or because the R&D program was highly successful in generating new innovations which created large positive spillovers to the nonsupported firms.

Such spillovers might not be such a problem in sectors for which knowledge has a high tacit component. Firms in such sectors might, however, invest more-or-less adequate amounts in innovation without strategic alliances or other support mechanisms, since the tacit nature of knowledge would offer them the prospect of appropriating most of the returns from an innovation.

Nor should one lose sight of the impact of evaluation schemes on incentives.[97] It should not be necessary to belabor this point to an audience the members of which have had to answer the question 'What do we need to know for the exam?' If students need good SAT scores to get into college and if high schools are evaluated based on how many of their students get into college, then it should not surprise if high school courses end up being organized not so much to educate, but rather to educate along the lines examined in SAT tests.[98]

Keeping these caveats in mind,[99] Table 1 lists targets that might be associated with strategic research alliances that pursue particular goals. Innovative activity proceeds along many dimensions, strategic research alliances have many targets (and, most likely, any one strategic research alliance will have multiple targets). How one measures depends on

Table 1. Strategic research alliance performance indicators

Target	**Index**	**Limitation(s) of index**
Increase knowledge	Peer review; publications, citations	Subjective; Edison problem: knowing that one line of research does not work is a result
Transfer knowledge in public laboratories to the private sector	Count number of cooperative agreements signed; survey private sector partners	Not all strategic alliances are created equal
Increase diffusion of (commercially applicable?) knowledge	Count patent licenses; count commercial applications; survey users; (event studies?)	Either requires subjective evaluation of patent, citation quality, or treats as equal things that are not
Augment absorptive capacity of commercial partners	*Ex post* survey, interview	Subjective; natural tendency to view one's own part of the world through rose-colored lenses
Increase level, effectiveness of private innovation	Econometric studies of R&D inputs or outputs	Inputs are not the same as outputs; output studies: not all patents are created equal; superfluous citations?; may be an index of benefit to private partners; does not take impact on rivals, consumers, into account; does not give indication whether benefits would have been obtained without strategic alliance
Correct insufficient innovation in a market estimation system	Full-fledged structural	Stringent information requirements

what it is that one wishes to measure and for each target, Table 1 lists possible evaluation methods (column 2) and possible limitations of the suggested evaluation method (column 3).

One might certify the output of research alliances that seek pure increase of knowledge through peer review, and evaluate the quality of output by measuring the number of publications generated, or citations of such publications. Peer evaluations, at their best, are objective, but also have an inevitable subjective element.[100] Further, as suggested by the remark of Thomas Edison cited at the beginning of the paper, negative results (which may be of differentially difficult publishability) add to knowledge.

Public sector-private sector strategic alliances might be evaluated by counting the number of such agreements signed by a public sector laboratory, or by surveying private-sector partners. Alternatively, they might be evaluated by counting the number of patent licenses resulting from alliances, by counting commercial applications, or by surveying users. Such approaches either treat all patents, all commercial applications as being of equal importance, or have an unavoidable subjective element. Public sector-private sector alliances that seek to augment the absorptive capacity of commercial partners might be evaluated, subjectively, by *ex post* surveys of commercial partners. Strategic R&D alliances that seek to increase the level and effectiveness of private innovation might be evaluated econometrically, comparing observed results with those that might have been obtained if the alliances had not been formed. The results of strategic alliances that seek generally to correct market underinvestment in innovation might also be evaluated econometrically. In both cases, carrying out the evaluation implies stringent information and estimation requirements.

This litany of limitations is not a plea to abandon evaluation. Rather, the point I wish to make is that any and all evaluation will be highly imperfect and that the results of project evaluation should be treated with appropriate caution.

Notes and References

1. S.H. Chan, J.W. Kensinger, A.J. Keown & J.D. Martin, 'Do Strategic Alliances Create Value?', *Journal of Financial Economics*, *46*, 1997, pp. 199–200.
2. W.G. Ouchi, 'The New Joint R&D', *Proceedings of the IEEE*, *77*, 9, 1989, pp. 1318–1326.
3. N.S. Vonortas, 'Inter-Firm Cooperation with Imperfectly Appropriable Research', *International Journal of Industrial Organization*, *12*, 3, September 1994, pp. 413–435.
4. The comments of W. Leontief, 'Letter to the Editors', *Science*, *217*, 9 July 1982, p. 106, are well known: 'Page after page of professional economic journals are filled with mathematical formulas leading the reader from sets of more or less plausible but entirely arbitrary assumptions to precisely stated but irrelevant theoretical conclusions.'
5. In some cases, at least, and to their credit, avowedly so (D.J. Teece, 'Firm Organization, Industrial Structure, and Technological Innovation', *Journal of Economic and Behavioral Organization*, *31*, 1996, pp. 193–224).
6. C. d'Aspremont & A. Jacquemin, 'Cooperative and Noncooperative R&D in Duopoly with Spillovers', *American Economic Review*, *78*, 5, December 1988, pp. 1133–1137.
7. Characterized by the assumptions of linear demand, quadratic cost of own-cost reduction, and deterministic R&D.
8. J. Hagedoorn & J. Schakenraad, 'Inter-Firm Partnerships and Co-operative Strategies in Core Technologies', in: C. Freeman & L. Soete (Eds), *New Explorations in the Economics of Technical Change* (London, Pinter, 1990).
9. Most of the literature that uses racing models assumes that if a firm undertakes R&D at all, it undertakes one R&D project (my own work falls in this category); much evidence is to the contrary. An exception is J.T. Scott, 'Historical and Economic Perspectives of the National Cooperative Research Act', in: A.N. Link & G. Tassey (Eds), *Cooperative Research and Development: The Industry University Government Relationship* (Boston, Kluwer, 1989).
10. The possibility that firm 1 might license full use of the technology that allows the cost reduction x_1 to firm 2 for a royalty payment $(1-\sigma)x_1$ per unit of output must surely have been considered in one of the many generalizations of the basic model. Such licensing does occur in the real world, and must be an element affecting the decision to carry out stand-alone or cooperative R&D.
11. M.I. Kamien, E. Muller & I. Zang, 'Research Joint Ventures and R&D Cartels', *American Economic Review*, *82*, 5, December 1992, pp. 1293–1306.
12. R. Amir, 'Modelling Imperfectly Appropriable R&D Via Spillovers', *International Journal of Industrial Economics*, *18*, 7, 2000, pp. 1013–1032.
13. Amir also includes monopoly R&D, as a point of comparison for the alternative modes of cooperation. The literature abounds with taxonomies of R&D cooperation, with definitions depending on the number of R&D operations, on whether or not formation of an R&D joint venture means an increase in the spillover parameter, on whether or not firms cooperate in production as well as R&D. For alternative classifications, see d'Aspremont & Jacquemin, *op. cit.*, Ref. 7; Hagedoorn & J. Schakenraad, *op. cit.*, Ref. 9; Kamien *et al.*, *op. cit.*, Ref. 12; and J. Hagedoorn, A.N. Link & N.S. Vonortas, 'Research Partnerships', *Research Policy*, *29*, 4–5, April 2000, pp. 567–586.
14. Much of the policy literature seems to take it for granted that firms cannot reduce the spillover rate, at least, not to zero. This is why appropriability of the revenue that flows from successful innovation is thought to be incomplete. There is also the possibility that if firms could reduce spillover rates to zero, they would not find it value-maximizing to do so; S. Martin, 'Spillovers, Appropriability, and R&D', *Journal of Economics*, *75*, 1, 2002, pp. 1–32.
15. See the account of Japan's VLSI project given by J. Sigurdson, 'Industry and State Partnership in Japan: The Very Large Scale Integrated (VLSI) Circuit Project', Swedish Research Policy Institute, University of Lund, 1986. See also the discussion, below, of P.B. Joly & V. Mangematin, 'Profiles of Public Laboratories, Industrial Partnerships and Organisation of R&D: The Dynamics of Industrial Relationships in a Large Research Organisation', *Research Policy*, *25*, 1996, pp. 901–922.
16. I resist use of the common term 'innovation market failure'. My own view is that if there are such things as markets for innovation, they tend to be narrowly defined: the efforts of pharmaceutical

firms seeking to develop an aids vaccine have not much to do with efforts to develop commercially applicable materials that will act as superconductors at room temperature.

17. K.J. Arrow, 'Economic Welfare and the Allocation of Resources for Invention', in: *The Rate and Direction of Inventive Activity: Economic and Social Factors* (Princeton, NBER, Princeton University Press, 1962), p. 615.
18. W.M. Cohen & D.A. Levinthal, 'Innovation and Learning: The Two Faces of R&D', *Economic Journal*, *99*, 397, September 1989, pp. 569–570. See also M.I. Kamien & I. Zang, 'Meet Me Halfway: Research Joint Ventures and Absorptive Capacity', *International Journal of Industrial Economics*, *18*, 7, 2000, pp. 995–1012; and Martin, op. cit., Ref. 15.
19. R.C. Levin, A.K. Klevorick, R.R. Nelson & S.G. Winter, 'Appropriating the Returns from Industrial R&D', *Brookings Papers on Economic Activity*, 1988, pp. 783–820.
20. P. Dasgupta & E. Maskin, 'The Simple Economics of Research Portfolios', *Economic Journal*, *97*, September 1987, pp. 581–595.
21. R.R. Nelson, 'Government Stimulus of Technological Progress: Lessons from American History', in: R.R. Nelson (Ed.), *Government and Technical Progress* (New York, Pergamon Press, 1982a), p. 455. See also R.R. Nelson, 'Public Policy and Technical Progress: A Cross-Industry Analysis,' in: R.R. Nelson (Ed.), *Government and Technical Progress* (New York, Pergamon Press, 1982b), pp. 1–7, reviewing case studies, and the discussion, below, of F. Tapon & C.B. Cadsby, 'The Optimal Organization of Research: Evidence from Eight Case Studies of Pharmaceutical Firms', *Journal of Economic & Behavioral Organization*, *31*, 1996, pp. 381–399.
22. Teece, *op. cit.*, Ref. 6.
23. Scott, *op. cit.*, Ref. 10, p. 68, notes that in its policy proposals 'the Reagan administration—surely at least in part because of its concern with declining competitiveness of US firms in global markets and in part because of its desire to deregulate markets—justified these policies by extraordinarily selective reference to theory and facts'.
24. In the EU, this policy stance is constitutional in its foundation: Article 81(3) of the EU Treaty makes the promotion of technological advance one basis upon which the European Commission may permit cooperation that would otherwise be prohibited under Article 81(1) (which sets out EU policy on cooperation among firms).
25. United States v. Automobile Manufacturers Association 1969 Trade Cases (CCH) Para 72,907 (C.D. Cal. 1969) (consent decree), modified 1982–3 Trade Cases (CCH) Para 65,088 (C.D. Cal. 1982).
26. P. Temin, 'Technology, Regulation, and Market Structure in the Modern Pharmaceutical Industry', *Bell Journal of Economics*, *10*, 2, Autumn 1979, pp. 429–446.
27. Nelson (1982b), *op. cit.*, Ref. 21.
28. Temin, *op. cit.*, Ref. 26.
29. W.S. Comanor, 'The Political Economy of the Pharmaceutical Industry', *Journal of Economic Literature*, *24*, 3, September 1986, pp. 1178–1217.
30. *Ibid.*, p. 1193.
31. S.B. Graves & N.S. Langowitz, 'Innovative Productivity and Returns to Scale in the Pharmaceutical Industry', *Strategic Management Journal*, 14, 1993, pp. 593–605.
32. R.E. Caves, M.D. Whinston & M.A. Hurwitz, 'Patent Expiration, Entry, and Competition in the US Pharmaceutical Industry', *Brookings Papers on Economic Activity Microeconomics*, 1991, pp. 1–48.
33. F.M. Scherer, 'Pricing, Profits, and Technological Progress in the Pharmaceutical Industry', *Journal of Economic Perspectives*, *7*, 3, Summer 1993, pp. 97–115, suggests that the prices of first varieties may actually rise after the expiration of patent protection, with much of the retail market supplied by the first variety at a high price and institutional demand supplied by generic substitutes at a lower price.
34. *Ibid.*
35. Similarly, J.T. Scott, 'Environmental Research Joint Ventures Among Manufacturers', *Review of Industrial Organization*, *11*, 5, October 1996, pp. 655–79, finds that the US Clean Air Act Amendments of 1990 were able to promote private investment to control specific targeted pollutants.
36. K. DeBackere & B. Clarysse, 'The Impact of Networking on Innovative Performance in New Biotechnology Firms: A Combined Econometric and Scientometric Analysis', Katholieke Universiteit Leuven, Departement Toegepaste Economische Wetenschappen Onderzoeksrapport No. 9748, 1997.

37. I. Cockburn & R. Henderson, 'Racing to Invest? The Dynamics of Competition in Ethical Drug Discovery', *Journal of Economics and Management Strategy*, *3*, 3, Fall 1994, pp. 507–508.
38. I. Cockburn & R. Henderson, 'Scale, Scope, and Spillovers: the determinants of research productivity in drug discovery', *Rand, Journal of Economics 27*, 1, Spring 1996, pp. 32–59.
39. Temin, *op. cit.*, Ref. 26.
40. Henderson & Cockburn, *op. cit.*, Ref. , p. 55.
41. I. Cockburn & R. Henderson, 'Absorptive Capacity, Coauthoring Behavior, and the Organization of Research in Drug Industry', *Journal of Industrial Economics*, *46*, 2, June 1998, p. 159. See also D. Mowery, 'The Relationship Between Contractual and Intrafirm Forms of Industrial Research in American Manufacturing, 1900–1940', *Explorations in Economic History*, October 1982, p. 352: 'the importance ascribed by many economic theorists to the appropriability of results from research may be misplaced. In understanding the organization and evolution of industrial research, the requirements for knowledge transmission and utilization, as well as the difficulties encountered in the negotiation and enforcement of contracts, acquire an importance equal or greater than that of the appropriability of the returns from research.'
42. G.P. Pisano, 'Using Equity Participation to Support Exchange: Evidence from the Biotechnology Industry', *Journal of Law, Economics and Organization*, *5*, 1, Spring 1989, pp. 109–126.
43. *Ibid.*, p. 124.
44. See S. Martin, 'R&D Joint Ventures and Tacit Product Market Collusion', *European Journal of Political Economy*, *11*, 4, April 1996, pp. 733–741 for a formal model.
45. G.P. Pisano, 'The Governance of Innovation: Vertical Integration and Collaborative Arrangements in the Biotechnology Industry', *Research Policy*, *20*, 3, June 1991, pp. 237–249.
46. The potential to worsen static market performance is present: if established firms systematically seal relations with small knowledge-intensive firms, costs of entry to the biotechnology sector might increase.
47. Pisano, *op. cit.*, Ref. 45.
48. J. Lerner & R.P. Merges, 'The Control of Technology Alliances: An Empirical Analysis of the Biotechnology Industry', *Journal of Industrial Economics*, 46, 2, June 1998, pp. 125–156.
49. See also A. Pollack, 'Biotech Companies are Curtailing their Reliance on Big Drugmakers', *International Herald Tribune*, 25 August 2000, p. 15.
50. Tapon & Cadsby, *op. cit.*, Ref. 21.
51. *Ibid.*, pp. 389–390.
52. See A.B. Jaffe, 'Real Effects of Academic Research', *American Economic Review*, *79*, 5, December 1989, pp. 957–70; and J.D. Adams & A.B. Jaffe, 'Bounding the Effects of R&D: An Investigation Using Matched Establishment-Firm Data', *Rand Journal of Economics*, *27*, 4, Winter 1996, pp. 700–721.
53. Despite the fact, as noted by P.A. David, B.H. Hall & A.A. Toole, 'Is Public R&D a Complement or Substitute for Private R&D? A Review of the Econometric Evidence', *Research Policy*, *29*, 4–5, April 2000, pp. 497–529, that to the extent that public policy promotes information dissemination, it may lower the expected profitability of later innovators discouraging follow-on innovation. R&D cooperation agreements that restrict the access of one party to the agreement to the results of the cooperation do not normally qualify for the EC block exemption permitting R&D cooperation 'because they do not, as a general rule, promote technical and economic progress by increasing the dissemination of technical knowledge between the parties' (EC Commission, 2000, Para. 64).
54. Joly & Mangematin, *op. cit.*, Ref. 16.
55. Nelson (1982a), *op. cit.*, Ref. 21.
56. R.M. Ham & D.C. Mowery, 'Improving the Effectiveness of Public-Private R&D Collaboration: Case Studies at a US Weapons Laboratory', *Research Policy*, *26*, 1998, pp. 661–675.
57. See C.S. Ciccotello & M.J. Hornyak, 'Cooperation via Contract: An Analysis of Research and Development Agreements', *Journal of Corporate Finance*, *6*, 2000, pp. 1–24, for an analysis of the terms of CRDA contracts. They do not assess the impact of contract form on CRDA performance.
58. Ham & Mowery, *op. cit.*, Ref. 56, p. 663.
59. Joly & Mangematin, *op. cit.*, Ref. 16, pp. 917–918.
60. A.B. Jaffe, M.S. Fogarty & B.A. Banks, 'Evidence from Patents and Patent Citations on the Impact of NASA and Other Federal Labs on Commercial Innovation', *Journal of Industrial Economics*, *46*, 2, June 1998, pp. 183–205.

61. *Ibid.*, p. 196.
62. *Ibid.*, p. 198.
63. D.P. Leyden & A.N. Link, 'Federal Laboratories as Research Partners', *International Journal of Industrial Organization*, *17*, 4, May 1999, pp. 575–592.
64. This reduced appropriability may be a private bad, but it is likely to be a social good. Furthermore, to the extent that the knowledge embodied in the innovation is tacit, public laboratory participation may not reduce appropriability to any significant extent.
65. F.R. Lichtenberg, 'The Effect of Government Funding on Private Industrial Research and Development: A Re-assessment', *Journal of Industrial Economics*, *36*, 1, September 1987, pp. 97–104.
66. J. Lunn & S. Martin, 'Market, Firm, and Research and Development', *Quarterly Review of Economics and Business*, *26*, 1, Spring 1986, pp. 31–44.
67. L. Cohen, 'When Can Government Subsidize Research Joint Ventures? Politics, Economics, and Limits to Technology Policy', *American Economic Review*, *84*, 2, May 1994, pp. 159–163.
68. S.J. Wallsten, 'The Effects of Government-Industry R&D Programs on Private R&D: The Case of the Small Business Innovation Research Program', *Rand Journal of Economics*, *31*, 1, Spring 2000, pp. 82–100.
69. *Ibid.*, p. 83.
70. M.T. Robson, 'Federal Funding and the Level of Private Expenditures on Basic Research', *Southern Economic Journal*, *60*, 1993, pp. 63–71, finds that Federal support increases private spending on basic R&D one-for one. However, he works with aggregate data.
71. S. Martin & J.T. Scott, 'The Nature of Innovation Market Failure and the Design of Public Support for Private Innovation', *Research Policy*, *29*, 4–5, April 2000, pp. 437–447, suggest a scheme of indirect public support for private innovation, with funding going in the first instance to venture capitalists, in effect reducing their cost of capital and allowing them to identify and fund R&D projects that would not otherwise receive funding.
72. S. Fölster, 'Do subsidies to cooperative R&D actually stimulate R&D investment and cooperation', *Research Policy, 24*, 1995, pp. 403–417.
73. Fölster (*ibid.*) distinguishes between information trading (of intermediate research results) among firms carrying out their own R&D projects and result-sharing within the context of a cooperative agreement. 'Result sharing' seems to be a secretariat R&D joint venture with complete information spillovers among cooperating firms.
74. S.A. Rosenfeld, 'Does Cooperation Enhance Competitiveness? Assessing the Impacts of Inter-firm Collaboration', *Research Policy*, *25*, 2, 1996, pp. 247–263.
75. D. Luria & E.Wiarda, 'Performance Benchmarking and Measuring Program Impacts on Customers: Lessons from the Midwest Manufacturing Technology Center', *Research Policy*, *25*, 2, 1996, pp. 233–236.
76. L.K. Westerback, 'Toward Best Practices for Strategic Information Technology Management', *Government Information Quarterly*, *17*, 1, 2000, pp. 27–41.
77. *Ibid.*, p. 38.
78. *Ibid.*
79. W. Boulding & R. Staelin, 'Identifying Generalizable Effects of Strategic Actions on Firm Performance: The Case of Demand-Side Returns to R&D Spending', *Marketing Science*, *14*, 3, 1995, pp. G222–236.
80. The PIMS (profit impact of market strategy) database is a privately maintained line-of-business database; see R.D. Buzzell & B.T. Gale, *The PIMS Principles* (NewYork, The Free Press, 1987).
81. S. Martin, 'Market, Firm, and Economic Performance', Salomon Brothers Center for the Study of Financial Institutions Monograph Series, 1983 (1), finds that greater line-of-business spending on R&D lowers line-of-business profitability, all else equal, while greater firm-level R&D spending increases line-of-business profitability.
82. Lichtenberg, *op. cit.*, Ref. 65.
83. S.A. Zahra & W.C. Bogner, 'Technology Strategy and Software New Ventures' Performance: Exploring the Moderating Effect of the Competitive Environment', *Journal of Business Venturing*, *15*, 1999, pp. 135–173.
84. S.H. Chan, J.W. Kensinger, A.J. Keown & J.D. Martin, 'Do Strategic Alliances Create Value?', *Journal of Financial Economics*, *46*, 1997, pp. 199–221.

85. X. Yang, M. Taylor & C. Stoltenberg, 'Assessing the Effects of Structural and Product Characteristics on R&D Strategic Alliance Performance', *Journal of High Technology Management Research*, *10*, 1, 1999, pp. 105–121.
86. *Ibid.*, p. 116.
87. Nelson (1982b), *op. cit.*, Ref. 21, p. 2.
88. On this point, see Luria & Wiarda, *op. cit.*, Ref. 75.
89. For examples, see R.C. Feenstra & J.A. Levinsohn, 'Estimating Markups and Market Conduct with Multidimensional Product Attributes', *Review of Economic Studies*, *62*, 1, January 1995, pp. 19–52; or M.J. Roberts & D. Supina, 'Output Price, Markups, and Producer Size', *European Economic Review*, *40*, 3–5, April 1996, pp. 909–921.
90. Not obviously more severe, however, than that confronted by Luria & Wiarda, *op. cit.*, Ref. 75.
91. T. Bresnahan & R. Gordon (Eds), *The Economics of New Goods* (Chicago, University of Chicago Press, 1997).
92. F.M. Scherer & D. Harho, 'Technology Policy for a World of Skew-Distributed Outcomes', *Research Policy*, *29*, 4–5, April 2000, pp. 559–566.
93. It should also be kept in mind that it may take some time before the value of an innovation is evident. Cournot did not even receive his first review, a harshly critical one, until after his death. The full import of his work did not begin to be appreciated until more than 100 years after it appeared. The fundamental innovation embodied in the ubiquitous post-it sticker was developed in 1968, the product first introduced in 1980 (http://www.3m.com/about3M/pioneers/fry.html).
94. Of course, if one is going to conduct peer review, one might as well do it *ex ante*, when it might have some effect on the allocation of resources. A.N. Link & J.T. Scott, 'Public/Private Partnerships: Stimulating Competition in a Dynamic Market', *International Journal of Industrial Organization*, *19*, 5, 2001, pp. 763–794.
95. Their estimates are a lower bound, as expected returns to consumers are not taken into account.
96. T.J. Klette, J. Møen & Z. Griliches, 'Do Subsidies to Commercial R&D Reduce Market Failures? Microeconomic Evaluation Studies', *Research Policy*, *29*, 4–5, April 2000, p. 482.
97. One might call this the Heisenberg evaluation principle.
98. If public universities emphasize both teaching and research in evaluating faculty performance, but the availability of external funding is related to research performance only, then it should not surprise if greater weight is given to research performance in evaluating … but I digress.
99. And recalling once again the motto of the Christopher Society: 'It is better to light one candle than curse the darkness'.
100. For a critical view of the peer review process, see B. Frey, 'Publishing as Prostitution? Choosing Between One's Own Ideas and Academic Success', 15 July 2002, *Public Choice*, forthcoming.