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HOW EFFECTIVE ARE GOVERNMENT R&D SUBSIDIES: THE EMPIRICAL EVIDENCE

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ABSTRACT

Government subsidized industrial R & D stands for a large and increasing segment of the total R & D conducted. Yet very little is known about the effectiveness of such subsidies. This paper summarizes the empirical literature concerning direct project subsidies, tax credits, and support for industrial research institutes. This helps to identify what makes government policy effective from the government's perspective and how it affects firms.

I. INTRODUCTION

Hand in hand with the disillusionement over demand policies as a remedy of slow growth governments all over the world have intensified efforts to kick-start ailing industries with aid to R & D. Common sense as well as circumstantial evidence suggests technology plays an important role in economic growth. Whether government subsidies can spark innovation is much less certain.

In most countries the public sector stands for a large segment of the total R & D. This is shown in Table 1. Public support for R & D also consitutes a rising segment of GNP in most countries. Even a large fraction of R & D conducted within industry is publicly financed, even though the differences between countries are large.

A growing number of studies have increased our understanding of technological advance (for a thorough survey see Stoneman, 1983). But little is known about the effects and effectiveness of government R & D policy. Results can however be dug out from a variety of disparate sources. This paper aggregates the evidence on direct subsidies, research institutes, and tax credits. Although the empirical results are patchy some clear indications emerge about how not to subsidize and in what directions to search for more effective subsidy policies.

When is government policy effective? To answer this question one must first determine what the aim of government policies ought to be. Here the quandary begins. Many times the stated aims of government agencies dispersing subsidies is at variance with the underlying economic arguments for supporting private R & D. Consider briefly what these economic arguments are.

WHY SHOULD THE GOVERNMENT SUPPORT INDUSTRIAL INNOVATION

Firms spend money innovating in expectation of resulting profits. The profits are large if few other firms innovate simultaneously, so that the firm enjoys a cost or quality advantage. Firms lose if rivals can imitate the invention and produce cheaply without having incurred research costs. Witness the microcomputer market. The first machines made millionaires because only few had the know how to build them. Now, with the technology in everyone's hands, many firms lose on their microcomputer production.

If the inventing firm does not capture all gain to an invention then it does not have sufficient incentive to research from a social point of view.[1] There will be some projects it discards even though they profit society. Imitation is not the only way a firm can be deprived of some the social benefits of innovation. It may not be able to capture the entire consumer surplus (i.e. the users' benefits from the invention), and some of the costs of educating researchers and engineers may be lost when these succumb to the lure of rivals or of independent ventures.

To ameliorate the problems with imitation the patent office was instituted. With an invention patented a firm stands a chance of being the sole exploiter, at least during the patent's life. This raises the return to the inventing firm and its incentive to research.

Unfortunately, there are three problems with patents. First, too often they do not work. Imitation, or inventing around the patent is too easy and may even be facilitated by the required disclosure of technical information during the patenting procedure.[2] Second, when patents work the inventing firm becomes a monopolist for the invention. Monopolies are known to engender social welfare loss. Third, patents are hard to adjust to individual circumstances. If imitation is easy the length of patent life may be irrelevant. If imitation is difficult patent life can be too long inducing too many firms to research toward the same invention too fast, each trying to win the patent race.[3]

If a patent fails to defy imitators not all is lost. Imitators face two other hurdles. First, the knowledge required to produce the invention may not be easily transferable. It may consist mostly of skills that employees have acquired. Would-be imitators must then move down a learning curve before they can compete; or they can try to lure employees from the leading firm. Second, the inventing firm can try to keep information about inventions secret. The trouble is that secrecy is expensive for the firm and adds nothing directly to society's welfare.

In sum the firm is likely to research insufficiently from a social point of view in areas where inventions are difficult to keep secret either because know-how leaks easily and patents protect poorly, or where results emerge only in the long run so that people with non-transferable knowledge may quit.

This is the main reasons for government intervention. But there are others as well. Two of these figure prominently in the debate. The first is that firms may be too risk averse to engage in projects that are large in relation to the size their company. Since society as a whole can spread risks better, and therefore is less risk averse, the government should then assume some of the risk of research projects or subsidize some of the riskiest projects.

The second argument is that some industries may be run by technologically backward management and institutions. In these cases governments have often opted for research institutes that serve to spread information and aid local technical advance. This approach has been common in connection with agriculture and small scale industry.

The reasons given in favor of supporting R & D apply equally to diffusion of technology. In fact what looks like R & D at the firm level often is nothing but adaptation of extant technology.

The existence of inefficiency in the market for innovation does not by itself justify government intervention if such intervention is excessively expensive or inefficient. One of the more expensive policies is to subsidize all research. Tax credits, discussed below in more detail, do precisely this. The idea behind direct project subsidies is to subsidize research only when government intervention makes a difference. Projects that have no social value or that the firm would conduct anyhow need not be subsidized as they are under a tax credit system.

The different reasons for government intervention, or objectives of government policy, may of course conflict. For example, aiding diffusion can reduce the time during which an inventor is the sole exploiter of a novel idea thus reducing his return and his incentive to research.

II DIRECT PROJECT SUBSIDIES

From the government's point of view there are three problems with subsidies to firms. The problem that attracts the most attention is that subsidies support projects that turn out to be white elephants, worthless to the firm as well as society at large. The other two problems are that firms sometimes are subsidized for research they would have conducted anyway and that the subsidy may distort incentives leading to less efficient research.

Of course firms themselves are not immune to white elephants even without government help. So the real question is whether the government more often supports projects that were poor investments at the time without the benefit of hindsight. Many consider this proposition basically untestable. Nevertheless a few empirical studies exist. For example Ettlie (1982), in a study of federally sponsored innovation projects in the U.S., finds that subsidized industrial projects lead to commercialized projects more seldom than unsubsidized projects (also Allen et al., 1978). Using an econometric approach that compares industry branshes in relation to government suport, Griliches (1980), Link (1981), and Terleckyi (1980) find that the rate of return to government-financed R & D appears far lower than that for company R & D. It is difficult however to infer from these results that subsidies are inefficient. The aim of the subsidies is after all to support projects that firms would not otherwise conduct but that are socially valuable due to indirect influences or because they are easily imitated. Thus the projects supported by the government should show a lower private return.

In order to determine whether government subsidies are awarded too often to unworthy projects one can examine what incentives the firm and the government have in allocating subsidies. When it is in the firm's interest to receive a subsidy it will naturally try to represent the project as having a significant social value. The government bureaucrat usually has small possibilities of checking the information supplied by the firm.

Further, the government bureaucrat deciding who is worthy of public funds and who is not has a self interest that may be at variance with the common good. Two typical cases are likely to arise. One is that of a politically motivated decision. There is some evidence reviewed below to suggest that government support often goes to showcase projects such as pilot plants that contribute little to overall innovation but serve well as evidence of a politician's or agency's initiative.

The other case, considered more carefully here, is that of a government employee, responsible for distributing a certain sum of subsidy funds. The problem that arises is that his superiors have an informational disadvantage in evaluating the administrator's performance. Usually there exists no data on the expected social value of projects, or on whether the firm would have conducted this research anyway without the subsidy.

The information that is most readily available is whether the supported project, after its completion, becomes a commercial success. The likelihood of a project succeeding commercially depends on two things. First, the administrator's skill in choosing winners and helping to shape the project so that it succeeds. Second the inherent riskiness of the project. But the less risky a project is, the greater the chance that the firm would have conducted it anyway and the less effective the government subsidy is in stimulating innovation. The administrator therefore has an incentive to pick non-risky projects that the firm would have researched anyway in order to make it appear as though his skill in spotting winners is great.

This is bad enough. Even worse, though, this mechanism implies that an increase in subsidy funds may reduce the total social value of research conducted. If firms apply with safe projects, knowing that the agent is more likely to fund these, then the greater percentage of cost is covered by the subsidy the more likely firms are to apply also with projects they would not otherwise have conducted in addition to applying with safe ones they would conduct anyway. If these safe projects have positive social values all is well. The total social value of research rises. If however they have negative social values - which is possible since they are safe projects with negative private values - then the total social value of research will decrease. In either case risky projects that have, say, a smaller chance of paying off highly and leading to significant advances never get a chance even if they have higher expected values.

The second problem with subsidies from the government's point of view is that firms receive subsidies for projects they would conduct anyhow. Naturally this is in the firm's interest. The subsidy is then a largesse for which no extra effort is required. Again it is very difficult for a government bureaucrat to ascertain whether a firm would or would not conduct a project.

The third problem is that the subsidy gives incentives to research inefficiently. This can occur if the subsidy is tied to certain conditions that may be politically motivated or that hinder a reformulation of research goals as new ideas arise. Also, this can be problematic if maximizing private return requires types of research that militate against social returns. For example a firm may put a lot of emphasis on developing defensive patents around an innovation that do not raise the invention's social value at all.

From the firm's point of view subsidies are generally welcome as extra income. There are a few reservations however. A great dependence on subsidies may weaken a firm's competitive edge. Many managers also claim that subsidy policies are not salient for their decision making, and that frequently they reduce the efficiency of projects due to bureaucratic constraints and delays (Rubenstein et al., 1977; Ettlie, 1983).[4]

Consider now the empirical evidence. One expects large differences in subsidies' effectiveness depending on how they are doled out. So it is important to correlate any findings with the type of subsidy program.

Three methods are then available to assess the success of susidies: Surveys among R & D managers, econometric studies comparing firms receiving support with those that do not, and case studies. Consider first the survey approach.

The main difficulty with this approach lies in the question one has to ask R & D managers: Would you have conducted this research project even without government support? If the answer is "no" one still does not know whether the project had any merit and should have been subsidized from a social point of view. In either case one must wonder whether managers are entirely honest: Do they fear a reduction of subsidies if they respond wrongly? Do they loathe the thought of appearing dependent on government handouts?

With these caveats in mind consider a few studies leading to opposite results. Mansfield (1984) reports a study of 41 federally funded energy R & D projects. He finds that firms would only have financed 20% of these projects themselves. Further each dollar increase of federal funding increased firms' R & D spending with 12 cents even though federally funded projects only appeared to add half as much to firms' productivity as firms' own spending on R & D.

Another study paints a much bleaker picture of government intervention. Gronhaug and Fredriksen (1984) examine the Norwegian innovation plan in existence since 1977. The plan includes grants covering 65% of project costs and low interest loans covering 85% of R & D costs which need not be paid back if the project fails. The projects were selected based on potential profitability, novelty of the project idea and the assumed R & D competence of the applying firm. The authors find that 78% of the projects would have been conducted anyhow, even though some of them on a reduced scale.

What can account for the difference in these studies? Upon closer inspection the two subsidy programs appear quite different. The Norwegian funds were granted to a variety of firms, each applying with their own research ideas. The government administrators in turn evaluated the projects in terms of commercial viability, without posting any own technological goals in the field.

Quite different the American energy support. Here the government came with a bag of own ideas, or developed ideas together with firms, in addition to supporting ideas originating in firms. Further the focus was less on narrow commercial viability and more on other goals such as developing techniques that could become viable in case of an energy shortage.

In interpreting either of these results one must remember that even if the part of unnecessarily subsidized projects represents a smaller fraction of total subsidies this can still place an intolerable burden on the efficiency of subsidies. A simple example can demonstrate this point. Suppose the firm increases the amount of its research by 50 percent of the value of the subsidy. Suppose further that additional research has a social return of 20 percent, remembering that these are marginal projects that the firm did not conduct without the subsidy. Then the social value of granting the subsidy is only 10 percent of the amount of subsidy. This may well be less than the social cost of raising the amount of the subsidy via taxes.[5]

A further study (Meyer-Krahmer et al., 1983) using the survey approach examines a German policy of subsidizing 25-40% of researchers' salaries in small and medium-sized firms. The authors conclude that the subsidies did not lead firms to engage in new projects. However, firms increased their spending on R & D personell by about 50% of the value of the subsidy.

The second approach of examining the efficiency of subsidies has been the econometric study comparing the extent of R & D in subsidized and unsubsidized firms. One problem of these studies is that it is difficult to infer a direction of causality. For example Scott (1986) finds, using U.S. data, that firms within each line of business that receive more government financing also conduct more own research. The problem here is that the government subsidies may not crowd in private research as inferred by the study. Rather firms with bright engineers may propose ideas that attract both firm funds and government aid. Lichtenberg (1984) attempts to correct for this by computing the correlation between the increments in the two R & D categories to eliminate the time-independent industrial characteristics. This is not a totally convincing technique because some changes in technological opportunities may favor increases in private as well as government R & D. In any case, this study finds that private R & D decreases when government subsidies are larger. A similar result is achieved by Carmichael (1981) and Levy and Terleckyi (1983). The latter conclude that government contracts and university research stimulate private R & D while subsidies seemed to reduce private research expenditure.

The third empirical approach consists of case studies. For example, Nelson (1982) presents case studies that reveal a pattern of relatively succesful intervention in basic research, "generic" technologies, and fundamental research areas such as health and agriculture where researchers, rather than government officials, make resource allocation decisions. When government attempted to "pick winners" and to intervene in the later stages of technological development, the results were substantially less favorable. Roessner (1984) shows on the basis of case studies how government R & D managers and administrators were under pressure to push technologies prematurely to commercialization status, implying highly inefficient and costly decisions. The primary source of this pressure were elected and appointed officials who sought the political rewards of short term highly visible, easily implementable programs.

MacDonald (1986), in a review of the Australian grant system for encouraging R & D shows that the grants are given to exactly the same kinds of projects that firms research anyway. Thus, he argues, the program loses much of its value.

TAX CREDITS

In many countries tax credits for R & D expenditures have been granted usually allowing a larger deduction for an increase in R & D expenditure rather than a level of expenditure. The advantages of such a policy are its low requirement in terms of bureaucracy and its political feasability.

Empirical studies (mainly Mansfield, 1986, also Bozeman and Link, 1984; Mansfield & Switzer, 1985) in Sweden and other countries seem to show that tax credits increased industrial R & D by about one third of the government revenue foregone. Moreover there was substantial evidence that the tax incentives resulted in a considerable redefinition of preproduction activities as R & D, especially in the first few years after the introduction of the tax incentive. Such redefinition of activities is estimated to have resulted in a total increase in reported R & D expenditures of about 13 to 14 percent in one country, Sweden, over the course of a few years.[6]

This means that the true elasticity of firm research with respect to the amount of a general subsidy is probably a lot lower than 30 percent. Roughly speaking that means that if a tax credit should be an effective policy it would have to stimulate research that is four or five times as valuable as direct government research.

Quite similar to tax credits are investment subsidies. These have also been found to have negligible effects on innovation (Folmer and Nijkamp, 1987).

GOVERNMENT RESEARCH INSTITUTES

Government research institutes serve two purposes: To conduct R & D that is socially valuable but that the firm does not conduct on its own and to help diffuse know-how. The argument is that research results attained in a research institute rather than in a firm can be spread to other firms instead of remaining secret. In particular small or medium sized firms, too small to research on their own, can order research from the institutes that also benefits other firms. A number of surveys have indeed found that industrial firms identify research institutes as the most frequently consulted source of extra-mural scientific and technical information (see Pavitt and Walker, 1976 ; Rothwell and Townsend, 1973).

Two main problems , reflected in the applied literature, afflict the government research institutes. First, researchers working in the government institutes may research the wrong projects. This may be because they have wrong incentives. For example they may be more interested in publishing articles than in designing new widgets. Or they may lack the firms' knowledge of what inventions are commercially viable.

Second, the kind of knowledge needed by industry to produce a new gadget may not be easily transferred. While the know-why of science is easily disseminated, the know-how of technology is locked up in individual employees' experience. Even when the knowledge is easily transferred the research institute employees may not have the right incentives to distribute this information and localize all potential users.

Much of the applied literature on government research institutes consists of case studies. Some of the somewhat more systematic attempts to evaluate government research institutes (e.g. Toren & Galai, 1978) typically find that the institutes are most useful for medium-sized companies in low-technology branshes. Small firms often lack the resources even to engage in contracted research at an institute. Large firms on the other hand do their own research. In high-technology branches firms are eager to keep research secret, so they do not like to involve outsiders.

The problem of information flows is examined in studies by Allen et al. (1983) and Leonard-Barton (1984). Allen et al., in a multi-country comparison show that technology flows principally through informal channels within industries. Very little of the total information flow was obtained from the formal mechanisms or institutions, such as research institutes, normally considered central to the technology transfer process. These studies focussed on high-technology firms which may explain the contradiction with the results referred to above.

Clearly, there is a dearth of empirical studies concerning research institutes. Not much more can be said at this point.

CONCLUSION

Even though each of the empirical studies can be criticised their combined conclusion is that many subsidy systems do not work very well.

One conclusion one might draw of this is that subsidies should be abolished. This would be an unfair conclusion because most of the empirical studies focus on very simple subsidy systems. A growing theoretical literature seems to suggest that government policies can be devised in a way that provides much more desirable incentives for firms and administrators. With respect to procurement contracts quite a number of schemes have been devised to this end (e.g. Weitzman, 1980). With respect to subsidies a scheme called the incentive subsidy has been suggested in Flster (1987). This scheme makes it in the firm's interest to accept a subsidy only for projects that have a positive social value and that it would not conduct anyway.[8]

Finding desirable alternatives to current policies will probably require some experimentation (e.g. Tassey, 1985). One danger is that experimentation is hampered by those who administer subsidy programs for precisely the same reasons that hamper current policies. Robbins and Milliken (1977) for example find that U.S. government experiments with different incentives had only limited success due to political pressure for early success which distorted objectives and encouraged policy demonstrations under conditions favoring "succesful" outcomes rather than true policy experiments.

FOOTNOTES

1. This is frequently called the "inappropriability" problem in the literature.

2. For example, Mansfield & Schwartz (1983) show that patents raise rivals' imitation costs by only small amounts. The exceptions to this result seem to be the chemical and pharmaceutical industries where patents are quite important.

3. From a social viewpoint a firm may research too much (e.g. Loury, 1979). This is likely when a number of firms race toward an important patent. From the firm's point of view time is of the essence, while from a social perspective expenditures may be unjustified that serve only to move the date of invention forward some. Thus in cases where patent protection is strong, or where firms for other reasons race toward similar inventions there may be excessive expenditure on substitute R & D. Certainly no subsidies are in order in this case.

4. Roessner (1979) argues, and supports empirically, the notion that in some industries demand is so uncertain that even large subsidies will stimulate innovation much less than confirmed orders. This is shown in a study of firms dependent on local government for their orders.

5. For an estimate of the cost of extracting taxes see Hansson, 1984.

6. In Sweden there was an R & D tax allowance equaling 5 % of a firm's R & D expenditure plus 30 percent of the increase over the previous year. This policy was terminated in 1984 due to doubts about its effectiveness.

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TABLE 1

TOTAL R & D AND
TOTAL PUBLIC EXPENDITURE ON R & D AS % OF GNP

	Total R&D 1984	Public Exp 1984	Public Exp 1979
Belgium	1.4	0.59	0.59
Denmark	1.2	0.54	0.48
FR Germany	2.5	1.12	1.13
Greece	0.4	0.24	0.19
France	1.8	1.45	1.09
Ireland	0.8	0.39	0.53
Italy	1.1	0.77	0.39
Netherlands	2.0	0.98	0.96
UK	2.3	1.35	1.07
Sweden	2.6	0.75	1.00
USA	2.7	1.13	1.32
Japan	2.6	0.60	0.65

Source: OECD, UNESCO