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by

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ABSTRACT

State subsidies to R & D or innovative investments in firms are organized in many different ways. Examples from the plethora of extant subsidy instruments are tax incentives, grants to researchers, project grants, loans, conditional loans, and grants with royalty rights. Very little is currently known about the effectiveness of these subsidy forms.

In this paper we compare the effectiveness of eight forms of subsidy for R & D projects. The comparison is based on a survey of Swedish R & D managers, including detailed information about 214 research projects or project proposals. In a first set of results we report managers' general judgements about the effectiveness of different subsidy forms. Second, R & D managers were asked to judge how each subsidy instrument would affect the firm's decision about the size of each project and whether to conduct it. This allows an estimate of how much additional R & D each policy might induce.

There are two main conclusions. First, general subsidies do not seem to induce much additional R & D for a given amount of subsidy. Second, among specific subsidies so called "stock option grants" seem to induce most R & D per subsidy krona. These are grants that give the state a right to recoup some of its funding by exercising a stock option if the firm's value rises rapidly. The main reason that the stock option grant performs well is not that the state can recoup some of its costs but rather that firms do not accept this subsidy for much of the research that they would have conducted even without subsidy.

1. INTRODUCTION

State subsidies to R & D or innovative investments in firms are commonplace in many countries. These subsidies differ considerably with respect to what exactly is subsidised and under what conditions the subsidy can be received. Sometimes these differences can be explained by the fact that different subsidies are directed at different target groups. In many countries however any particular target group will be eligible for a variety of different subsidy instruments, all purportedly aimed at stimulating R & D or innovativeness. A closer look at the policy discussions concerning subsidy instruments conveys the impression that subsidy instruments are often chosen for their administrative advantages rather than their efficiency in generating additional R & D. This can probably be explained by the fact that very little is known about the efficiency of different subsidy instruments.

Economic theory provides some general results concerning the use of subsidies to correct market failures as well as some analysis of the market failures that may stand in the way of innovation (e.g. Dasgupta, 1988). This literature provides a good understanding of some basic factors, but it offers little guidance for choosing between, say, loan guarantees and project grants as subsidy instruments. Some attempts at theoretical comparisons between subsidy instruments can be found in Fölster (1988, 1989). Since a theoretical comparison is too lengthy to be included here the focus in this paper lies entirely on empirical comparisons .

In theoretical models the "efficiency" of subsidies is easily defined as the change in some social welfare function. For empirical purposes however efficiency has usually meant how much additional R & D is generated for a given cost to the public purse. Undoubtedly this definition ignores a number of efficiency aspects such as the extent to which the conduct of R & D is adversely affected by the subsidy application procedure and subsidy regulations. Nevertheless it probably captures the central element and it is tractable empirically. Thus in the following we take the term efficiency to mean the additional R & D generated for a given outlay.

A few previous empirical studies have endeavoured to estimate the efficiency of different subsidy instruments. These are also reviewed at length in Fölster (1989). Three different empirical methods are used. One is the case study. The other are econometric estimates of the correlation between subsidization and R & D intensity across industries or firms. The third method consists of surveys. All of these studies concern one or other existing policy, and in no case, as far as we are aware, is an attempt made to compare the impact of different subsidy instruments on similar projects.

Case studies (e.g. Roessner, 1984) always leave the question open of how representative the studied cases are. The econometric studies (e.g. Lichtenberg, 1984) have to date not been able to convincingly discern the direction of causality in the correlations between the amount of subsidy and the amount of firm R & D spending. A common finding is that total R & D expenditure is larger in industries that receive subsidies, but the difference in R & D expenditure is smaller than the

amount of subsidy. Such correlations can be explained either by the fact that subsidies stimulate R & D or by the fact that firms receive greater subsidies if they have promising research ideas and, therefore, greater incentives to invest themselves. As a result of this problem our judgement is that survey methods are as likely to produce useful answers as econometric studies are.

The survey studies fall into two groups. One approach has been to query respondents about their general judgements concerning a policy. The other is to focus on specific decisions and ask how they would have been changed in the presence of a policy (e.g. Gronhaug & Frederiksen, 1984; Mansfield, 1986). In this paper we do both. This provides a control of the extent to which respondents merely draw on their general judgements when they reconsider specific decisions. The specific decisions in turn permit a quantitative estimate which is necessary for a judgement of whether subsidies are socially worthwhile.

Our survey among Swedish firms includes projects that firms conduct as well as projects that firms for the time being have decided not to conduct. Roughly half of the firms were large firms with more than 100 employees (571 employees on average). The other half were venture firms with 24 employees on average.

The subsidy instruments we analyse are listed in Table 1. They can be divided into three categories: General subsidies, Selective self-financing subsidies, and selective non-self-financing subsidies. Selective subsidies are those that are approved on a case by case basis. Self-financing subsidy

systems include repayment provisions that make it theoretically possible that the subsidy program as a whole will be self-financing. Whether these systems actually are self-financing in practice depends of course on the exact provisions and on the projects that are subsidized.

TABLE 1

SUBSIDY SYSTEMS

GENERAL SUBSIDIES

1. Tax deduction for R & D expenses
2. Grant toward costs of R & D personell

SELECTIVE NON-SELF-FINANCING SUBSIDIES

3. Project grants
4. Project loans at low interest rates
5. Conditional loans that are repaid only if R & D is succesful

SELECTIVE SELF-FINANCING SUBSIDIES

6. Fee-based loan guarantees
7. Royalty grants, royalty to the state is based on sales of the invention toward which the grant was applied.
8. Stock option grants, in return for an R & D grant the state receives a stock option that can be exercised if the stock value rises significantly. For large firms the stock option refers to separate venture companies set up around the respective R & D project.

Section 2 describes the survey design. Section 3 reports the research managers' general judgements of policy effectiveness. In section 4 the quantitative estimates of policy effectiveness are shown.

2. THE SURVEY DESIGN

The survey was carried out via personal- and telephone interviews. Such interviews rather than a questionnaire were deemed necessary because the questions were relatively complicated. Early trial runs indicated that respondents needed a fair amount of explanation in order to be willing or able to answer.

The questions were designed with guidance from the theoretical literature on subsidization and on technological change and the empirical literature on the efficiency of R & D subsidies. The interviews were held with high-level R & D managers, usually with responsibility for the R & D of a business unit.

The R & D managers were asked to report typical experiences or central tendencies within their line of business. They were thus treated as informed observers of the industry. In addition they were asked to select a number of representative R & D projects and were asked specific questions about these projects.[1] Some of these projects had been rejected and were not actively pursued. Respondents were asked to pick rejected and accepted projects in about the frequency with which they were proposed. For example an R & D manager rejecting about half of all well-defined project proposal would be asked to answer questions about an equal number of accepted and rejected projects.

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1 A project is defined to be a fairly well-specified research proposal that can be accepted or rejected without significantly affecting the remainder of the firm's research activity.

Respondents were told that they need not divulge the technical nature of the projects so there was no reason for them to give misleading replies in order to protect secrecy.

SAMPLE CONSTRUCTION

The total sample consists of 61 respondents. Of these 33 are R & D managers of large business units with more than 100 employees. 28 are managers of small, newly started, firms usually organized around a single product or line of business. Each of the R & D managers of large business units gave details about 3-5 research projects. The managers of small firms gave details of two or three projects. In total the number of projects in the sample amounts to 214, of which 135 come from large firms and 79 from small firms.

Firms were chosen so as to make the sample representative of Swedish industry with one important caveat. Firms that do not conduct R & D were excluded. In total the sampled firms conduct about 6% of Swedish private R & D. No projects that currently receive subsidies were included.

METHODOLOGICAL ISSUES

Because of the small number of firms in each industry we do not attempt to distinguish between industries. Some of the variance in the data may be explained by industry differences although none of the differences in evaluations of policy effectiveness are statistically significant between industries.

There is considerable variance in judgements of policy effectiveness between projects, even within each firm. This is reassuring because it means that respondents did not

indiscriminately apply their general judgements to specific projects.

In the first part of our survey managers were asked about their general judgements of the effectiveness of the policies. The answers are reported on a seven-point Likert scale ranging from "not at all effective" to " very effective." There is no natural or objective anchor for such evaluative ratings. Individuals may perceive the same environment but simply use the scale differently. Some might systematically favor high scores; others might concentrate responses in the center of the scale. A number of techniques are available to control for differences among respondents in mean and variance. These techniques however impose the restriction of assuming a "true" uniform mean or variance. Rather than impose such restrictions we let the second part of our survey that depends on quantitative estimates rather than semantic scales act as a test of robustness.

Survey results are often biased by the ordering of questions. To avoid this problem we randomized the order in which questions were asked.

3. GENERAL JUDGEMENTS OF POLICY EFFECTIVENESS

R & D managers were asked how effective they believed different subsidy instruments to be in terms of stimulating additional private R & D at the lowest cost to the public purse. Respondents were asked to rate their judgement of effectiveness on a 7-point Likert scale ranging from 1=not at all effective to 7= very effective.

Table 2 reports the results. The first two columns show the overall sample means for large and small firms respectively. The results are robust to the use of alternative summary statistics such as the median.

TABLE 2

There is a clear pattern in the results. Apart from fee-based loan guarantees the self-financing instruments are generally rated higher than non-self-financing instruments. In particular the general subsidies were rated low. Interestingly a number of managers commented that, if given a choice, they would prefer general subsidies even though they did not believe these to be an effective way of raising the level of R & D. Apparently managers had no difficulty in distinguishing between the firms' interests and the public interest.

Stock option grants were rated highest for both categories of firms.

In follow up questions we asked managers why they rated subsidy instruments in the way they did. We cannot report all responses here. Rather we summarise the comments that were shared by at least 20% of the respondents.

1. General subsidies were thought to attractive due to their administrative simplicity. They were thought to be rather ineffectual however because the thin spread of subsidies to all research means that the impact on any particular project is small.

2. Small firms were thought to be in greater need of capital. Thus subsidies to small firms were thought to have a

greater effect. An additional consequence is that grants have the advantage over loans of not affecting small firms' already extended leverage.

3. The fee-based loan-guarantee scheme was viewed with suspicion. It was thought that unless it contained a large subsidy component it would be taken up largely by those already planning to default.

4. The stock option grant and royalty grant was thought by many to be attractive because "it resembles what private investors do." Since firms initially receive a grant their leverage is not affected, and the self-financing component is activated in proportion to the success of the project. Therefore these instruments were thought effectively to reduce risk while at the same providing the state with a way of recouping costs.

4. JUDGEMENTS OF POLICY EFFECTS ON SPECIFIC PROJECTS

The research managers' general judgements shown above provide some insight. It is quite unclear however how robust they are. Further it is unclear whether, in the absence of a quantitative estimate, the stimulative effect of subsidies is large enough to justify their social cost.

In order to make quantitative estimates each R & D manager was asked to choose a number of representative R & D projects, including some that the firm had decided not to conduct at the moment. It was stressed that the ratio of conducted to non-conducted projects should approximate the proportions in which projects actually ocurred in the firm.

For each conducted project managers were then asked, for one subsidy instrument at a time, whether they would apply and to what extent the receipt of a subsidy would raise the firm's investment in the project. For each non-conducted project managers were asked whether they would conduct the project under each subsidy scheme and how much they would invest.

To be meaningful these questions require an exact definition of the size of the subsidy under each system. The conditions for each policy were specified in ways that roughly correspond to policies that actually exist. An additional consideration was that the total public expenditure implied by the subsidies should be as equal as possible. Since the definitions had to be fixed a priori it was of course not possible to align public expenditure exactly. Table 3 shows the exact subsidy specifications.

TABLE 3

DEFINITION OF SUBSIDY SYSTEMS

1. Tax incentive: 30% of R & D costs can be deducted from taxable firm income.

2. Grant to R & D personell: 20% of the wages of R & D personell are paid.

3. Project grants: 50% of project costs are paid.

4. Project loans: 70% of the project costs can be borrowed at a zero interest rate.

5. Conditional loans: 70% of the project cost can be borrowed at market interest rate and need not be repaid if the project fails. Failure means that the invention is not used or sold.

6. Fee-based loan guarantees: For a fee of 2% (large firms) or 5% (small firms) of the size of the loan 100% of the project cost can be borrowed at market interest rates. In case of bancruptcy the state picks up the loan.

7. Royalty grants: A grant of 50% of the project cost is given in return for royalty payments worth 5% of total revenues on the new product.

8. Stock option grants: A grant of 50% of the project cost is given in return for an option to purchase stocks within the next ten years at current prices and a volume of stocks corresponding to the amount of the grant at current stockprices. In large firms a separate venture company is formed around the project and the stock option refers to this venture company.

Our results about the effectiveness of subsidy instruments necessarily refer only to the exact specification of the instruments as shown above. This is unfortunate in the sense that a subsidy instrument that we find to be inferior to another actually may be superior with a different specification. This opens considerable scope for further research. One would expect however that if a subsidy instrument had dramatically different effects with a different specification then this should be reflected in the general judgements reported in the previous section. We take the fact that the general judgements coincide fairly closely with the quantitative effects as evidence that the subsidy instruments display similar efficiency even with different specifications.

Another consequence of using exact specifications is that the total public cost of each subsidy system cannot easily be held equal for all subsidy instruments. In particular for the general subsidies the total public expenditure is determined entirely by the managers' responses. For the other instruments however it is possible to fix the total budget and grant the subsidy to as many projects as the budget allows. Thus, given the managers' responses one can manipulate one policy

parameter, the total budget, even though the size of the subsidy per subsidized project cannot be changed.

For some of the policy instruments additional questions had to be asked to determine the size of public outlays required. These questions and the exact procedures for calculating public outlays are reported in the appendix.

In the Table 4 we show with how many projects firms would have applied to each of the subsidy instruments. In general firms would have applied with most of the projects that they conduct anyway to the general and non-self-financing instruments. In some cases however firms reject subsidies. In follow-up questions managers indicate that in some instances they are worried about maintaining secrecy about projects when applying for a subsidy to a public agency. In other cases the subsidy instrument does not work. In particular the tax incentive is not taken up by all firms because it only represents a subsidy to firms that earn a profit.

The self-financing subsidies are taken up much less frequently for projects that firms would have conducted anyway.

Of the projects that firms do not currently conduct a the firm would accept the subsidy, and thus conduct the project, for some fraction of projects.

TABLE 4

To provide a proper comparison of policies we must simulate the selection of projects that receive selective subsidies. We assume that the general subsidies are granted to all firms that

apply. The selective subsidies are applied only to a subset of projects selected from all projects that firms say they would apply with. This selection process essentially expresses how accurately the subsidizing agency can distinguish projects that should be subsidized from those that should not. We examine three levels of information that subsidizing agency might have:

1. PERFECT INFORMATION: Of all projects that apply only those projects receive a subsidy that either would not have been conducted without the subsidy or where the investment in the project is increased by at least half the amount of the subsidy.

2. IMPERFECT INFORMATION: Half of all projects are selected as with the perfect information criterion. The other half are selected as though the state had no information at all so that all that apply receive the subsidy.

3. NO INFORMATION: All projects that apply are subsidized.

Tables 5, 6, and 7 show the amount of new R & D generated per krona of public expenditure for the three levels of information.

The general subsidies have the same effect in all tables since they are not affected by the assumptions concerning project selection. The general subsidies show relatively poor ratios of R & D generated to public expenditure.

The selective non-self-financing instruments perform fairly well under perfect information but with poor information they perform poorly. Since they are given indiscriminately with poor information one would expect them to perform

similarly to general subsidies. Table 7 confirms this suspicion.

The loan guarantee is fairly insensitive to information levels. The reason is that so few firms apply to this scheme, in particular with projects they would have conducted anyhow. As a result this instrument may not appear inefficient in comparison with general subsidies but it certainly is ineffectual. Little new R & D is generated even though the costs to the public purse are not high.

The royalty grant and stock-option grant are also relatively insensitive to information levels. Again the reason is that few firms apply with projects they would have conducted anyway. As whole these grant systems, and particularly the stock-option grant, appears to generate most R & D per public expenditure.

As a test of the robustness of our results one can compare them with an estimate of the elasticity of R & D with respect to research costs. To do this we asked firms what effect a cost reduction of 10% would have on each project. The response to that questions indicates an elasticity of R & D with respect to research costs of 0.26. This is in line with findings in previous research (e.g. Mansfield, 1986). It also fits well with our survey results. One would expect a R & D cost reduction to have a slightly greater effect on R & D than an equivalent general subsidy since the subsidy may be judged to be more uncertain.

6. CONCLUSION

A survey of research managers' reactions to hypothetical subsidies is used to compare the effectiveness of different subsidy instruments. The robustness of the results is confirmed by a number of checks. First, managers do not just give their general judgement but also judge how specific projects would be affected by the subsidies. Second, manager's judgement of the effect of hypothetical cost reduction reveals an R & D elasticity that is in line with the findings of previous research.

The main results are the following. The subsidy instrument that seems to perform best is a so called stock option grant. In general self-financing instruments seem to perform better and to be less sensitive to conditions of poor information. The only exception are loan guarantees that were viewed with considerable suspicion.

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APPENDIX

The total public expenditure for each subsidy instrument is calculated as shown below. The survey contained questions about the project costs, number of employees, and duration that were used for all of the subsidy instruments:

1. Tax deduction. If the firm was earning a profit the public expenditure was calculated using the corporate tax rate that the firm had actually paid in the previous year. If the firm did not earn a profit the public expenditure was assumed to be zero. This means that we ignored the possibility of carrying over losses to future years.

2. Personell grant. Here the public expenditure is simply a function of actual or planned R & D personell and the duration of the project.

3. Project grant. Public expense is calculated as 50% of the project costs.

4. Project loan. Here the present value of the interest subsidy is calculated assuming a constant rate of inflation.

5. Conditional loan. Managers were asked how likely they thought that the project would be succesful. Succesful was defined as meaning that the R & D costs would be recouped. Then managers were told that they should expect to repay the loan with the same likelihood. Public expenditure was calculated using the likelihood that managers reported.

6. Fee-based loan guarantee. Here independent estimates of the likelihood of bancruptcy were used. These were derived from a sample of similar firms.

7. Royalty grant. Managers were asked the rough order of expected sales for product innovations. The royalty grant was

applied only to product innovations. These estimates and project duration were used to calculate public expenditure.

8. Stock-option grant. To calculate public expenditure we make an extremely rough, but conservative, estimate of the value of the stock-option. In fact, with our assumptions the value of the stock option does not reduce public expenditure much. We assume that firms earn a total real profit of 2% (of R & D costs) a year on each conducted project. Then, assuming a constant p/e ratio we calculate how this would affect stock prices. For firms without listed stock prices we impute these using book values.

TABLE 2

GENERAL JUDGEMENTS OF SUBSIDY EFFECTIVENESS

	SAMPLE MEANS LARGE	SMALL	ALL FIRMS
1. Tax incentive	2.1 (0.11)	3.2 (0.13)	2.5
2. Grant to R&D personell	2.4 (0.12)	3.1 (0.13)	2.5
3. Project grants	2.8 (0.10)	3.3 (0.12)	3.0
4. Project loans	2.5 (0.13)	2.9 (0.14)	2.3
5. Conditional loans	3.0 (0.11)	3.5 (0.11)	3.3
6. Fee-based loan guarantees	1.5 (0.14)	2.2 (0.13)	1.8
7. Royalty grants	3.2 (0.16)	3.9 (0.18)	3.5
8. Stock option grants	3.6 (0.11)	4.2 (0.12)	3.9
All Policies	2.6	3.2	2.8

Source: Authors calculation
a. Range 1 = not at all effective; 7 = very effective; Standard errors in parentheses.

TABLE 4

NUMBER OF PROJECTS THAT WOULD APPLY FOR SUBSIDY
in % of conducted and non-conducted projects

	CONDUCTED PROJECTS		NOT CONDUCTED	
	LARGE	SMALL	LARGE	SMALL
1. Tax incentive	95	71	10	8
2. Grant to R&D personell	100	100	13	9
3. Project grants	91	97	22	25
4. Project loans	87	96	19	21
5. Conditional loans	87	97	17	23
6. Fee-based loan guarantees	2	15	0	5
7. Royalty grants[a]	32	34	18	29
8. Stock option grants	14	29	19	23
Total	63	67	15	17

Source: Authors calculation

[a] Only projects resulting in products were applicable to royalty grants. These were 55% of projects in large firms and 68% of projects in small firms. Here the percentage of applicable projects is shown.

TABLE 5

RATIO OF R & D GENERATED BY THE SUBSIDY TO PRESENT VALUE OF THE SUBSIDY WITH PERFECT PROJECT INFORMATION

	LARGE	SMALL
1. Tax incentive	0.19	0.08
	(0.06)	(0.07)
2. Grant to R&D personell	0.16	0.07
	(0.06)	(0.07)
3. Project grants	0.82	0.96
	(0.07)	(0.08)
4. Project loans	0.80	0.91
	(0.08)	(0.08)
5. Conditional loans	0.82	0.98
	(0.07)	(0.09)
6. Fee-based loan guarantees	0.74	0.61
	(0.005)	(0.008)
7. Royalty grants	0.92	1.12
	(0.11)	(0.13)
8. Stock option grants	0.99	1.17
	(0.09)	(0.10)

Source: Authors calculation
The standard errors are shown in parentheses.

TABLE 6

RATIO OF R & D GENERATED BY THE SUBSIDY TO PRESENT VALUE OF THE SUBSIDY WITH IMPERFECT PROJECT INFORMATION

	LARGE	SMALL
1. Tax incentive	0.19	0.08
	(0.06)	(0.07)
2. Grant to R&D personell	0.16	0.07
	(0.06)	(0.07)
3. Project grants	0.41	0.52
	(0.06)	(0.07)
4. Project loans	0.4	0.59
	(0.05)	(0.07)
5. Conditional loans	0.47	0.64
	(0.06)	(0.08)
6. Fee-based loan guarantees	0.48	0.47
	(0.01)	(0.02)
7. Royalty grants	0.56	0.74
	(0.10)	(0.11)
8. Stock option grants	0.72	0.92
	(0.09)	(0.10)

Source: Authors calculation
The standard errors are shown in parentheses.

TABLE 7

RATIO OF R & D GENERATED BY THE SUBSIDY TO PRESENT VALUE OF THE SUBSIDY WITH NO PROJECT INFORMATION

	LARGE	SMALL
1. Tax incentive	0.19	0.08
	(0.06)	(0.07)
2. Grant to R&D personell	0.16	0.07
	(0.06)	(0.07)
3. Project grants	0.21	0.30
	(0.05)	(0.06)
4. Project loans	0.18	0.27
	(0.06)	(0.07)
5. Conditional loans	0.21	0.29
	(0.06)	(0.07)
6. Fee-based loan guarantees	0.36	0.32
	(0.005)	(0.01)
7. Royalty grants	0.51	0.70
	(0.08)	(0.09)
8. Stock option grants	0.68	0.90
	(0.08)	(0.10)

Source: Authors calculation
The standard errors are shown in parentheses.