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THE "INCENTIVE SUBSIDY" FOR GOVERNMENT SUPPORT OF PRIVATE R&D

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ABSTRACT

An "incentive subsidy" policy for subsidizing private R & D is proposed that can be more efficient, from a social point of view, than subsidy policies in common use such as a "normal" subsidy policy (fixed amount granted at project start), and conditional loans (loan is repaid only if project is profitable).

The incentive subsidy compensates firms for any private loss and taxes away any gain; in addition the firm receives a small fraction of the resulting invention's social value. This mechanism comes close to being perfectly incentive compatible.

The firm chooses itself whether it wants to be covered under the incentive subsidy. Generally, the firm's choice coincides with three social aims: First, a project that the firm would conduct in any case should not be subsidized. Second, a project should not be subsidized if its social value is negative. Third, the subsidy should provide an incentive to maximixe a project's social value.

Using a simulation over a range of hypothetical research projects it is shown that the efficiency of conditional loans and normal grants declines drastically as the government's information about project parameters becomes poorer, while the incentive subsidy performs consistently well.

I. INTRODUCTION

Most governments spend rather large sums in support of private firms' innovation efforts. These funds are distributed in a variety of ways, most commonly as project grants, subsidized or conditional loans, or in the form of general subsidies such as tax credits. In this paper a subsidy scheme is proposed that seems to fulfil the government's aims better than most policies in current use. This is shown theoretically and in a simulation over a range of hypothetical projects.

Governments intervene with innovation subsidies because some research is neglected by firms even though it has a positive social value. A firm may be too risk averse to conduct a project that it would otherwise undertake; or an invention may have a larger social value when it diffuses so the firm cannot capture all of it. Such a positive externality may make it unprofitable for the firm to research even though it ought to from a social point of view.

Rather than subsidize all research to alleviate these market failures the government can save public funds by supporting only projects that are socially valuable and that firms would not conduct of own initiative. Thus the government agencies employed to dole out subsidies face three major problems: First, they must identify research projects that are socially worthwhile. Second, they should avoid subsidizing projects that the firm would conduct even without the subsidy. Third, the firm must have an incentive to conduct this research efficiently, using all opportunities for cost reduction and improvement of the prospective invention that arise.

The subsidy policies in common use often fall far short of fulfilling these three criteria. Tax credits, as an extreme case, support all projects regardless of merit. Normal project grants or subsidized loans are distributed somewhat more discriminatingly; here the government agency tries, based on previous experience and what it is told by the firm, to discern whether the project should, from a social point of view, be subsidized. Alas it is tricky not to be hoodwinked by a firm in whose interest it is to collect subsidies even for projects that it was in any case planning to research.[1]

In practice very little is known about the effectiveness of subsidy policies. The few available empirical studies seem to indicate that firms often receive subsidies for research projects that they would have conducted even without the subsidy.[2] The theoretical literature on this topic is largely confined to comparisons of stylized patent and subsidy policies without much attention committed to how these are administered (e.g. Wright, 1983).

In a previous paper (Fölster, 1987) it was shown that under reasonable circumstances a perfectly incentive compatible subsidy policy that solves all the three problems mentioned above cannot be devised.[3] Here the incentive subsidy is suggested as one of the most promising second-best alternatives.

The argument for the policy proposed in this paper proceeds along the following lines. First it is shown how the incentive subsidy works and why it comes close to achieving incentive compatibility (section II). Then the incentive subsidy is shown to be more effective than normal subsidies and conditional loans (section III). These are the two policies most frequently observed in practice. This result is then confirmed in a simulation, showing for a hypothetical distribution of projects that the policy proposed here performs increasingly better than the conditional loan or project-specific grants when the government's information about projects deteriorates (section IV).

The incentive subsidy eliminates the need for an ex-ante judgement by the government agency on whether a project should be subsidized. Instead the exact size of the subsidy is determined after the project has been conducted. This ex-post adjustment of the subsidy is done in such a way that the firm usually applies for the subsidy only when it should be subsidized from a social point of view. Under the incentive subsidy firms are reimbursed for any private loss they make and any private profit is taxed away; in addition the firm receives a small fraction of the invention's social value. As a result it will conduct a subsidized project in a way that maximizes social value. Also it applies only if its project has a positive expected social value and a small or negative expected private value.

A possible objection to the incentive subsidy is that it requires estimation of research projects' social and private value. Such estimates can be extremely uncertain.[4] This uncertainty however is not a serious problem for the incentive subsidy. It is shown that even large errors in the estimates of social value affect the efficiency of the incentive subsidy rather little. The reason is that the firm will not know in which direction the government errs until after the project is completed. Also, in comparison to the other subsidy forms an error is much less serious because the estimate is made ex-post with the results in hand rather than ex-ante as required by the normal subsidy and the conditional loan. More about the estimation of social and private values is said below.

II THE INCENTIVE SUBSIDY

Under the incentive subsidy scheme firms must apply prior to the commencement of a project. At that time firms may or may not receive an advance loan.[5] The important thing is that the exact size of the subsidy is not determined until after the project has been completed.

The incentive subsidy contains a component that compensates the firm for a loss or taxes away a gain it makes on the project. In addition the firm is rewarded a fraction a of the social value S.[6] This induces socially efficient research. The subsidy g is then as follows, where R is the private return, and the tax of profit or compensation for loss corresponds to - R :

$$(1)\quad g = - R + a S$$

The expected value of researching to the firm with the subsidy is $R^s = E(R + g) = a S^e$. Here S^e is the expected social value. As a result the firm does not apply with any project that has a negative expected social value.

Since the firm is rewarded for maximizing the social value it conducts the project efficiently, minimizing costs and maximizing the social value of the innovation.[7]

When a project has positive private return, so that $R > 0$, then the firm usually looses by applying to the subsidy system because the private return will be taxed away. However there is a special case, as mentioned above, where the incentive subsidy is not perfectly incentive compatible. The firm will lie about some projects it would have researched even without the subsidy, and will receive funding for them. If the firm is risk neutral this occurs for projects that have an expected unsubsidized private return R^u:

$$(2) \quad 0 < R^u < a S^e .$$

As long as the government correctly estimates R and S after the research has been conducted, a can be held extremely low, provided only that the firm does not treat it as negligible. Then there are probably only few projects within any reasonable distribution for which the incentive subsidy fails.

If firms are risk averse the incentive subsidy also acts as an insurance. Suppose a firm has a project with a positive R^u that is too risky for it to conduct. Then without the subsidy it gains nothing, but with the subsidy it expects a small return $a S^e$ involving little risk. So it will opt for the subsidy. The government can then expect a net return of $R^u - a S^e$. This is akin to an insurance where the premium is paid afterwards.

DETERMINING THE OPTIMAL LEVEL OF a WHEN GOVERNMENT ESTIMATES CONTAIN AN ERROR

If a firm is not risk averse then even a small value for the parameter a will induce it to research in a socially optimal way. Things are slightly more complicated when firms are risk averse and the government makes ex-post mistakes in determining the value of R and S. Suppose first that there are no systematic mistakes, so that the firm expects the government to be correct on average. Then joining the incentive subsidy will become more of a risky business for firms. To compensate for this the level of a must be set at a somewhat higher level as shown below. The important point is however that even ex-post government mistakes in judging R and S probably do not affect the efficiency of the incentive subsidy greatly as long as the mistakes are not systematic and predictable by firms.

To show what the optimal level of a is for a given project, suppose that the government forms ex-post estimates of the social and private values of a project, each containing the error, e_R and e_S respectively, with zero means and any standard deviation :

(3) $S^g = S + e_S$ $\qquad$ $R^g = R + e_R$

Both R and S are known to the firm and are assumed to be functions of a firm effort w, so that R = R(w) and S = S(w). It is assumed that S > R and that both are convex differentiable functions of w with S'(w) > 0, R'(w) > 0, S''(w) < 0, and R''(w) < 0.[8] It follows that the socially optimal w^s is larger or equal to the privately optimal w^R. Further it is assumed that there are non-convexities in the industry research production set. This means that some research projects may be conducted in a socially optimal way even without a subsidy. If this were not the case then the best policy could be merely to reimburse all firms for the difference between social and private values. The non-convexity however means that the government may save public funds by selectively subsidizing only projects that firms would not conduct otherwise (this argument is shown formally in Fölster, 1987).

With the incentive subsidy the firm expects a return of

$$(5) \quad V = R + g = a S^{g} - R^{g} + R$$

and it maximizes a utility function assumed to take the following simple form: $U = E(V) - m o_{V}$. Then o_{V}, the standard deviation of the firm's return is

$$(6) \quad o_{V} = E(a S^{g} - R^{g} + R - a S)^{2} = (a e_{S} - e_{R})^{2}$$

This shows that the standard deviation of V is independent of w. So the firm maximizes its utility by setting $U'(w) = 0$. This yields the result that the firm sets w to the socially optimal value at w^{S}, which is also the w at which $S'(w) = 0$.

The government in turn maximizes $E(S - r V)$ s.t. $U > 0$ and $a \geq 0$. Here r is the opportunity cost of raising public funds. The constraints exist to ensure that the firm will research under the subsidy scheme and to ensure that it maximizes social value. Taking the derivative shows that the parameter a is then set as small as possible to just fulfil the constraints:

$$(7) \quad a > (m o_{V})/ S$$

and

$a \geq 0$

This shows that as long as the government makes no systematic error, so that the error's expected value is zero, firms will set w to its socially optimal level regardless of the choice of a - provided that the constraints in (7) are satisfied.

Of course the government will not know the level of risk aversion among firms, so it may have to set a common a for all firms. The less accurate a is set then the larger the chance of not fulfilling the constraint that $U > 0$ exactly with as small an a as possible. This implies that some errors are committed with the incentive subsidy.

Things become worse when the government makes systematic mistake. Suppose, as an extreme case of neglect, it never takes firm effort w into account when reimbursing the firm. Then $V = a S^g - R^g + R - w$. The optimal w for the firm is then where

$$(8)\ U'(w) = a S'(w) - 1 = 0$$

This means that w is set at a level below the socially optimal level. Further, the firm increases w as a increases and it reaches its socially optimal value only when $a = 1$.

This means that if systematic mistakes become unavoidable, say in the case where a single inventor is subsidized whose effort cannot be observed, then the problem is transformed into a traditional principal agent problem. In this case the incentive subsidy requires a larger a; but a large a implies a wider range of projects where firms cheat and apply with projects they would have conducted anyhow. While the efficency of the incentive subsidy is impaired when the government commits systematic errors the other two subsidy forms suffer detrimental effects that are at least as large. This is shown in the following sections. The reason is that the systematic error also leads to mistakes in granting normal subsidies or conditional loans.

III THE INCENTIVE SUBSIDY IN COMPARISON

This section presents the theoretical arguments that support the incentive subsidy as a superior alternative to normal subsidies and conditional loans.

The arguments are based on the following assumptions. The government can estimate the social value of a research project before (ex-ante) it is conducted and afterwards (ex-post). The ex-post evaluation is always as least as accurate as the ex-ante evaluation, but often much more accurate.

The first principle is that a subsidy is more effective if the decision to subsidize is based on more accurate information. This shows why the incentive subsidy and the conditional loan outperform the normal subsidy. With a normal subsidy the government evaluates a project ex-ante. Then it signs a check with few strings attached. Information that emerges ex-post - but that the firm may have secretely known all along - is ignored.

The conditional loan is more refined.[9] Here the firm is required to pay back its subsidy if the project returns a private profit. The government can always set the size of the conditional loan exactly equal to the normal subsidy and, neglecting the available ex-post information, grant this loan to exactly the same firms that would have received the normal subsidy. Neglecting all ex-post information means that the loan is never retrieved. It follows that one can always do at least as well with the conditional loan as with the normal subsidy policy.

Since the government uses the ex-post information, available under the conditional loan scheme, only when this is expected to raise social value, the conditional loan will always be a better policy tool when the ex-post information is better than ex-ante information.

Similarly the incentive subsidy can be made to grant exactly the same sums to firms as the normal subsidy by neglecting ex-post information and setting the parameter a to zero.

The normal subsidy has two further problems apart from using ex-ante information. First, it does not reward increases in social value. Second, it does not reduce the risk to firms as much as the conditional loan and the incentive subsidy. Both of the latter pay out larger sums when the project fails than when it succeeds. Since a risk averse firm values a unit subsidy more in the event that it is making a loss than when it is making a profit the same expected value of a subsidy raises utility less with the normal subsidy. This also means that one can get the firm to research, by raising its expected utility above zero, with a lower level of expected government handouts under the conditional loan and incentive subsidy. Since government handouts have an opportunity cost it follows that a lower government expenditure is a definite advantage.[10]

Comparing the conditional loan with the incentive subsidy is slightly more complicated. The main problem with the conditional loan is that one cannot tax the firm if the project turns out to be privately profitable. As a result firms will apply for the loan even with projects that they would conduct anyhow, but that have a chance of returning a private loss. Another problem is the fact that the conditional loan does not reward improvements in social value.

The incentive subsidy can always be made to perform at least as well as the conditional loan. This is apparent from the fact that the exact size of the incentive subsidy can be adjusted to any desired amount based on all available ex-post information about the private and social return. When granting a conditional loan on the other hand the size of the potential subsidy must be determined based only on ex-ante information. Ex-post information can be used only in a very restricted way to determine how much of the loan should be repaid. One can never ask the firm to repay more than it received in the first place. This means that the incentive subsidy can be set at exactly the same level as the conditional loan if the government gives up some of its freedom to act upon ex-post information. Assuming that the government only uses the greater freedom with the incentive subsidy when this is expected to raise social value, it follows that the incentive subsidy is better.

More precisely, the incentive subsidy has the following advantages.

1. The first problem with the conditional loan is that it does not reward social efficiency. Thus if the social value of a project can be raised by incurring some extra expenditure then the firm with the conditional loan will never do so, while under the incentive subsidy the government can adjust the parameter a to induce the firm to do what is socially efficient.

2. With the conditional loan firms will try to get loans for projects that they would conduct anyhow but that have a chance of failing. The poorer the government's ex-ante information is the poorer it will be at weeding out those projects. With the incentive subsidy this type of mistake occurs only for projects where the expected utility of a S is larger than the expected private profit. This ought to be an unusual case since a can be set at a low level.

3. The conditional loan reduces risk for the firm less than the incentive subsidy because the size of the loan does not vary with the extent of private loss. This means that a somewhat larger payment may be required in order to get the firm to research.

It must be emphasized that this comparison of subsidy policies is valid even if the government makes mistakes in estimating the social value. The reason is that mistakes in estimating social value affect all policies. While systematic mistakes have similar effects for all policies, random errors are less serious for the incentive subsidy because they are committed after the firm has conducted its project. Since the firm does not know in which direction the error will occur it will presumably research in the socially most efficient way.

IV A SIMULATION

The comparison of subsidy policies in the previous sections has isolated the factors that determine the relative efficiency of the policies without really shedding much light on the quantitative importance of the efficiency differences.

This is a difficult theoretical task mainly due to the problems in specifying general optimality conditions for the size of subsidies over a distribution of distinct projects when adverse selection and cheating must be taken into account.

Instead this problem is solved numerically in a simulation model. The simulation has been performed a large number of times with varying assumptions. The pattern of results is always similar. Here a typical set of results is presented. It is shown that the incentive subsidy suggested in this paper performs better than the conditional loan and the normal subsidy. However, when the government has perfect information the difference between the subsidy policies is small. When the government has poor information the conditional loan and the normal subsidy perform considerably worse than the incentive subsidy.

The simulation is performed over a range of 30 projects. For each type of subsidy policy the simulation model determines whether and how the project is conducted by firms and what the social value is. The social values are then added to show the efficiency of a policy over the entire range of projects. The detailed assumptions of the model are supplied in the appendix. In short, each project contains an uncertainty of succeeding better or worse. Firms calculate what subsidy they are to receive uncer each possible project outcome and thus arrive at an expected private value and a utility level (to account for risk aversion). Of the 30 projects 8 have negative expected social and private values, 11 have a positive social value and negative private utility level, and 11 have positive private and social values.

Table 1 shows a typical set of results. The values shown are percentage increases in social value due to the respective subsidy policy being introduced. Apart from the three subsidy policies discussed in this paper the table shows results also for a hypothetical perfectly incentive compatible policy. This represents the maximum increase in social value possible, in effect when firms act as if their interests were identical with the government's.

Four different assumptions are made about the accuracy of the government's estimates of social values. The first column assumes no errors at all. The second and third column assume a small and a severe random error. The fourth column assumes a systematic overvaluation of the true social values. The specific representation of these errors is explained in the appendix.

The results show that when the government is well informed all subsidy policies perform relatively well. When the government is not well informed then the normal subsidy and the conditional loan perform relatively worse while the incentive policy still performs quite well.

When there is a systematic bias in the governments evaluation of social values then all policies perform worse, but the incentive subsidy retains its relative advantage.

VII CONCLUSION

It is argued that the incentive subsidy is a better policy than either the normal subsidy policy or the conditional loan that are commonly used in many countries.

Theoretical arguments lead to the conclusion that the conditional loan is a better policy than normal project grants and that the incentive subsidy is a better policy than the conditional loan.

Finally a simulation of the different policies over a range of hypothetical projects compares the policies when the government has imperfect information about the projects. It is shown that the worse the government's information is the better the incentive subsidy performs relative to the other policies.

APPENDIX

All firms have the same utility function with constant absolute risk aversion. Due to the risk aversion not all projects with positive expected private values have positive expected utilities.

It is assumed that public funds have an opportunity cost of 10%. The projects themselves have a value that contains a constant component T, and a component t ln(w) that the firm determines itself by choosing an effort w. In addition there is a random component o that has a 50% chance of being added or subtracted. The expected social value of a project is then:

$$(1)\quad S^e = T + t \ln(w + 1)(1 + s) - w + 0.5\, o - 0.5\, o$$

The social value of a project is higher than its private value, due the parameter s, that is set equal to 0.7 here.4

So the private expected value is

$$(2)\quad R^u = T + t \ln(w + 1) - w + 0.5\, o - 0.5\, o$$

Maximizing with respect to w gives an optimal private w^p = t - 1 and an optimal social $w_s = t(1 + s) - 1$. In the simulation T increases in increments of 1 from -15 to 14 thus creating 30 projects. t is set to 4 and o to 10.

To account for risk aversion the form for constant absolute risk aversion is used: $U = 1/q(1 - \exp(-q X))$. q is set to 0.13 and X is the actual firm return.

With perfect government information the subsidies are calculated as follows:

1. Hypothetical perfectly incentive compatible subsidy: This is the amount required to compensate firms for researching in a socially optimal way, assuming that there are no incentive problems. Thus if R^U is negative then $g = - R^U + (w_s - w_p)$ and if R^U is positive then $g = w_s - w_p$.

2. Incentive subsidy: the parameter a is set to 5%.

3. Normal subsidy: For all projects that have $S^e - r g > 0$ the subsidy is set so that the firm will just research, EU = 0.

4. Conditional loan: As for the normal subsidy, given that the firm has to repay if R > 0.

When the government does not have perfect information, then it makes mistakes in estimating the project parameter o. The error e is assumed to follow a binary distribution so that o is estimated at (o + e) or (o - e), each with a 50% chance. e is set at the levels 3 and 8. The policies are then set as follows:

1. Incentive subsidy: The private return and the

social value are estimated with an error. The optimal policy is just as in the perfect information case.

2. Normal subsidy: The social and private values are estimated with an error, leading to mistakes in deciding what the level of subsidy should be. The optimal subsidy turns out to be 0.6 times the perfect information subsidy when e = 3, and 0 when e = 8.

3. Conditional loan: The social and private values are estimated with an error, leading to mistakes in deciding what the level of the loan should be and how much should be repaid. The optimal loan turns out to be 0.8 times the perfect information loan when e = 3, and 0.7 times the perfect information case when e = 8.

When the government commits systematic errors, e.g. consistently overestimating the social value, the subsidies are calculated as in the perfect information case above. The only difference is that now the government's estimate of social value is taken to be twice the true social value.

FOOTNOTES

1. Another problem is that it is tempting for government officials to avoid subsidizing risky private projects that may fail and expose the government official to criticisms of lack of judgement. This may result in a bias toward technically safe projects. Unfortunately, it is exactly these projects that the firm is most likely to conduct of own accord. Thus this bias leads to more cases where the subsidy has been wasted.

2. The empirical literature has been summarized e.g. in Pavitt (1976) and Fölster (1986). Examples of studies are Gronhaug and Frederiksen (1984) and Mansfield (1984).

3. Specifically it was shown in Fölster (1987) that if the government has no ex-ante information about research projects except what it is told by firms (but perfect ex-post information), then a subsidy function cannot be devised that ensures that the following two conditions are met for any project that firms can apply with: First, no project with a negative social value or a positive private value is subsidized. Second, a firm researches in a way that maximizes social value.

4. The claim is sometimes made that it is virtually impossible to value many inventions. As a counterargument one need look no further than the stockmarket where venture capital firms with risky research projects are valued by private agents all the time. So the real question is not whether these values can be estimated, but rather how seriously mistakes in this valuation damage the efficiency of the policy.

5. Advance loans become necessary only when capital markets do not function perfectly. This may be the case in practice. Correcting imperfections in the capital market should be treated as a separate problem however, requiring a separate remedy. The incentive subsidy as such solves only one market failure. Amending the incentive subsidy with loans ameliorates a different market failure and is therefore not further considered here.

6. The social value can be calculated by following a set of rules of thumb. The firm may know these rules in advance, but it will not know how the government judges specific values until the project has been concluded. In practice it may be debatable when exactly a project is concluded. It is hard to believe however that this constitutes a major problem.

7. Since the incentive subsidy rewards a firm for increases in social value it may also be used to increase the rate of diffusion of a technology. For example if the firm can show that it has helped other firms to use its invention as well then the estimated social value will be greater and the firm will earn a greater return.

8. Empirical studies tend to find that social returns to inventions are much larger than private returns, e.g.

Mansfield et al. (1977).

9. For example STU, the main government agency dispensing research subsidies in Sweden, grants a considerable fraction of its budget in the form of conditional loans. Of these subsidies roughly 25% are repaid (STU, 1983).

10. Public funds have a higher opportunity cost than the firm's funds because they consist of the private opportunity costs of whoever they were taxed from as well as the deadweight loss of taxation. For estimates of the opportunity cost of public funds see for example Hansson (1984).

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	perfect inform.	small gov error	large gov error	systematic gov. error
1. Incentive subsidy	26	23	16	9
2. Normal Subsidy	19	12	- 6	2
3. Conditional loan	22	17	5	5
4 .Hypothetical perfectly incentive compatible subsidy	28	25	19	12

TABLE 1
PERCENT INCREASE IN SOCIAL VALUE OVER
THE NON-SUBSIDIZED OUTCOME