The effects of governmental financing on firms' R&D activities: a theoretical and empirical investigation

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Abstract:
There is a long history of governmental support for private innovative activity in the U.S.A. However, the economic research on this topic has been narrow in focus, emphasizing primarily the relationship between the level of governmental R&D and the corresponding (in a causal sense) level of private R&D. In this paper, we explore the effects of governmental financing on another aspect of private innovative behavior—the sharing by firms of innovation-related knowledge. Based on a simple model of private innovative activity in the face of an exogenous governmental R&D contracts/grants structure, we find, among other things, that governmental R&D allocations spur industrial R&D laboratories toward greater sharing of their innovation-related knowledge.

Article:

1. INTRODUCTION

The U.S. government has a long history of supporting innovative activity dating back to 1789, with the U.S. Navy's sponsored research programs, and to the mid-1800s, with the Department of Agriculture's involvement in the land-grant college system. Since World War II, direct governmental support of industrial R&D has increased dramatically, though cyclically, in response to both military needs and the government's responsibility for enhancing research capabilities, as outlined in the National Science Foundation Act of 1947. Moreover, indirect governmental support for industrial R&D has risen as a result of the adoption of Section 174 of the 1954 Internal Revenue Code, which codified and expanded tax laws pertaining to a firm's R&D expenditures. Additional indirect support has come about as a result of a number of recent policy initiatives such as the R&D tax credit portion of the Economic Recovery Tax Act of 1981, the National Cooperative Research Act of 1984, and the Federal Technology Transfer Act of 1986.[1]

Spurred by the work of Blank and Stigler [3], empirical studies have investigated the effect of direct governmental R&D support on the level of private R&D spending and have generally found a complementary relationship between the two.[2] However, such efforts have not concentrated on the degree to which such support affects the nature of the output of private R&D. Given the continuing debate over the appropriate role for governmental involvement in stimulating innovative activity, it would appear important to know whether current programs affect not only the level of private innovative activity but also the sharing of that activity.

The purpose of this paper is to investigate the degree to which direct governmental R&D support affects the level of private R&D and the degree to which that private R&D is shared with others. Section 2 provides the theoretical foundation for our study. A profit maximizing firm is assumed to produce technology-based knowledge through the input of self-financed R&D, governmentally-financed R&D and other knowledge. The firm earns profits through the use of its technology-based knowledge in the production of a final product. The government injects itself into the private R&D decision-making process through the provision of contracts and grants. Firms, though ignorant of the form of the contracts/grants structure, see the level of governmental funds and adjust their behavior in order to maximize profits. Section 3 evaluates the model empirically using data from a recent survey of corporate R&D laboratories. Finally, Section 4 summarizes the implications of the empirical findings and offers some concluding observations.

2. A MODEL OF GOVERNMENTAL INFLUENCE ON INNOVATIVE ACTIVITY

Industrial firms that engage in innovative activity often have only a general notion of the interaction between innovative activity and profits. Typically, a firm does not have sufficient knowledge of the production function for technology-based knowledge to coordinate perfectly both the level of R&D funding and the manner in which it conducts R&D activity. As a result, R&D decision making is often performed through a groping process. The firm chooses a level of funding based, in part, on R&D output. The research laboratory alters its conduct in reaction to the new funding level and produces a new level of technology-based knowledge. This latter knowledge is then used in the production process for some final product; and profits result. In the model below, we assume this groping reaches an equilibrium through an iterative process. In essence, we model the firm *as if* it were composed of two players, each seeking to maximize the firm's overall profits given detailed knowledge, and therefore control, of only a portion of the entire production process. This approach is a simple example of the theory of teams. Schotter and Schwiidiauer (ref. 6, p. 494) define teams to be "sets of economic agents who have the same common objective function, but [which] must coordinate their activity in the presence of uncertainty and ignorance of each other's actions".

Assume, then, an industrial firm composed of a corporate R&D laboratory that seeks to maximize total profits through the production of technology-based knowledge, and all other administrative departments (referred to hereafter as the administrative department). The quantity of the R&D laboratory's knowledge Y is a function of the level of self-financed R&D activity C, the level of governmentally financed R&D activity accruing to the firm G and the degree to which the firm acquires knowledge from other sources α:

$$Y = f(C, G, \alpha) \tag{1}$$

Assume further that Y is a positive and strictly concave function of its inputs and that all inputs are non-negative. Finally, assume that greater knowledge enhances the marginal product of self-financed R&D as:

$$\frac{\partial^2 Y}{\partial \alpha \, \partial C} > 0$$

Because the output from the R&D process is technical knowledge, and because knowledge is by its nature non-depletable (non-rival), the publicness of Y will depend inversely on the degree to which Y is appropriated by the firm or, conversely, the degree to which the firm's laboratory shares its R&D output with others. We assume that sharing involves both the giving and the receiving of knowledge. Hence, α represents both the degree to which the firm acquires knowledge from other sources and the degree to which it shares its knowledge with others. Let α be defined (indexed) on the unit interval with a higher value of a indicating a greater degree of sharing. Finally, assume the level of α is chosen by the R&D laboratory while its level of R&D C is chosen by the administrative department.

Guiding the two departments in their choice of C and α is the effect that these variables have on profits. The laboratory's output Y is assumed to be an input into the production of the firm's final product. The total revenue R associated with that final product is assumed to be a positive but declining function of Y and a negative and decreasing function of α. Thus:

$$R = r(Y, \alpha) \tag{2}$$

with $\partial^2 R / \partial \alpha \, \partial Y < 0$.

The presumption behind the inclusion of a in the revenue function is that a greater level of sharing will result in a smaller competitive advantage in the marketplace, and therefore less of an ability to garner revenues through higher prices.

The firm incurs three types of costs in generating profits: the cost of its self-financed R&D, the cost of sharing and the cost of producing the final product. Designating these costs as C, A(a) and F respectively, we define profits to be:

$$\pi = r(Y, \alpha) - C - A(\alpha) - F \tag{3}$$

Assume that A(α) is a positive but declining function of α. Note also that the production costs associated with the final product *F*, are for the purposes of this model fixed.

Government enters the above decision making process as a separate player with its own objectives. The specification of the government's objectives, as well as the method for achieving them, is an issue of concern. It can be argued that the government has a role in fostering the production of public goods. According to this argument, the rationale for governmental contracts/grants is, in part, to stimulate the creation of productive knowledge in the private sector in order that the optimal level of growth in the economy can be attained. Hence, contracts/grants would be a function of such factors as the level of self-financed R&D, the degree of sharing, and the national importance of the research conducted *B. It* is not clear, however, whether governmental R&D contracts/grants are, in fact, designed to foster efficient levels of productive knowledge. The public-choice literature suggests that governmental programs may be designed to maximize the political objectives of those in control. Hence, we might alternatively expect the allocation of contracts/grants to be related to such things as the public visibility of research, the closeness of ties between the laboratory and the government, and the political value of the firm. Because it is beyond the scope of this paper to explore which of these alternative explanations more closely parallels reality, we hypothesize the following simplified solution to the government's problem:

$$G^* = g(C, \alpha, B, P) \quad (4)$$

where *P* represents factors considered politically important. In keeping with our desire not to examine the motivations of government in detail, we assume only that the government is not perversely (negatively) influenced by *C* or by α.

By assumption, the firm does *not* know eqn. (4). It only knows the size of the potential contracts/grants. Similarly, the government knows only the level of α and *C*. It knows nothing of the firm's internal decision making process.

The model's equilibrium can now be detailed. Given that the government treats the choice of the firm's sharing α and the firm's own R&D expenditures *C* as exogenous, and given that each department within the firm treats governmental R&D allocations *G* and the decision of its fellow department as exogenous, equilibrium is arrived at through an iterative process. Figure I presents a schematic view of how the three decision variables *(C*, α and *G)* combine to affect the firm's profits.

The optimal level of governmental R&D allocations *G**, has already been characterized above. For the firm, the optimal levels of *C* and α, *C** and α*, will be determined by each department's desire to maximise total profits. For the administrative department, the optimal level of self-financed R&D is defined by the following first-order condition:

$$\frac{\partial \pi}{\partial C} = \frac{\partial R}{\partial Y}\frac{\partial Y}{\partial C} - 1 = 0 \quad (5)$$

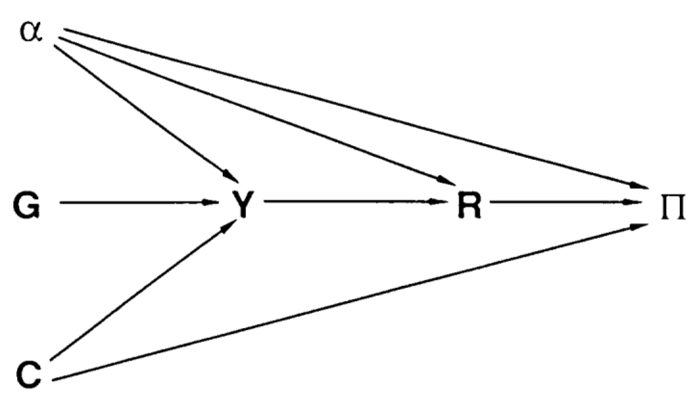

Fig. 1. Schematic view of the model.

while for the R&D laboratory, the optimal level of sharing is defined by:

$$\frac{\partial \pi}{\partial \alpha} = \frac{\partial R}{\partial \alpha} + \frac{\partial R}{\partial Y}\frac{\partial Y}{\partial \alpha} - \frac{\partial A}{\partial \alpha} = 0 \qquad (6)$$

These two first-order conditions are similar to the familiar 'marginal revenue product equals marginal cost of input' conditions and are therefore reminiscent of demand functions—the firm's demand for internal R&D investments and the firm's demand for knowledge sharing. Thus, the optimal levels of C and α, conditional on the other decision variables, can be written:

$$C^* = c(\alpha, G) \qquad (7)$$

$$\alpha^* = \alpha(C, G) \qquad (8)$$

The equilibrium of the model is defined by the system:

$$C^* = c(\alpha^*, G^*) \qquad (9a)$$
$$\alpha^* = \alpha(C^*, G^*) \qquad (9b)$$
$$G^* = g(C^*, \alpha^*, B, P) \qquad (9c)$$

Certain relationships underlying the system in eqns. (9) are of particular interest. Because the level of self-financed R&D is determined by the administrative department equating the marginal revenue product of C (MRP_c) to its marginal cost (see Fig. 2), a rise in MRP_c will result in a rise in C^*; likewise, a fall in MRP_c will induce a fall in C^*. Hence, as the following equation indicates, a rise in α has a theoretically indeterminate effect on C^*:

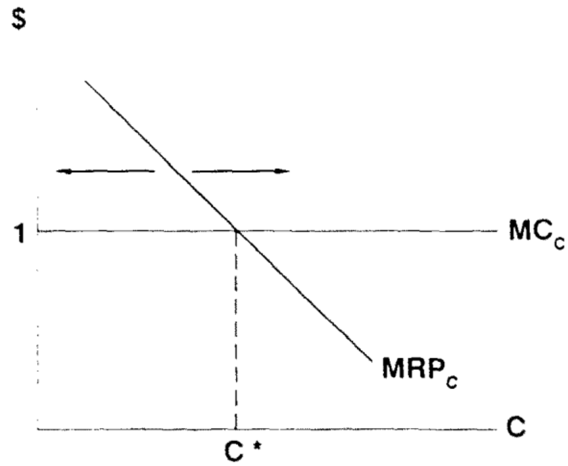

Fig. 2. Determination of optimal self-financed R&D. Note: $MRP_C = (\partial R/\partial Y)\partial Y/\partial C$.

$$\frac{d\,MRP_C}{d\alpha} = \overset{(-)}{\frac{\partial^2 R}{\partial Y \partial \alpha}}\;\overset{(+)}{\frac{\partial Y}{\partial C}} + \overset{(-)}{\frac{\partial^2 R}{\partial Y^2}}\;\overset{(+)}{\frac{\partial Y}{\partial \alpha}}\;\overset{(+)}{\frac{\partial Y}{\partial C}} + \overset{(+)}{\frac{\partial R}{\partial Y}}\;\overset{(+)}{\frac{\partial^2 Y}{\partial C \partial \alpha}} \gtrless 0 \qquad (10)$$

The first term of eqn. (10) indicates that a rise in α reduces MRP_c. by lowering the firm's competitive advantage (in Fig. 1, α affects R directly and therefore feeds back to C through Y), while the second term indicates that a rise in α reduces MRP_c by reducing the marginal revenue product of Y (in Fig. I, α affects R through its effect on Y and therefore feeds back to C through R). Finally, the third term indicates that a rise in α increases MRP_c by increasing the marginal physical product of C in producing Y (α affects Y and therefore feeds back to C directly).

The effect of governmental R&D on the optimal level of self-financed R&D is also theoretically indeterminate, though for a different reason than above. A rise in G results in two effects:

$$\frac{d\,MRP_C}{dG} = \overset{(-)}{\frac{\partial^2 R}{\partial Y^2}}\;\overset{(+)}{\frac{\partial Y}{\partial G}}\;\overset{(+)}{\frac{\partial Y}{\partial C}} + \overset{(+)}{\frac{\partial R}{\partial Y}}\;\overset{(?)}{\frac{\partial^2 Y}{\partial C \partial G}} \gtrless 0 \qquad (11)$$

The first effect of a rise in G is to lower the marginal value of C in generating revenues through its increase in the level of Y (G affects R by way of Y and therefore feeds back to C through Y). The second effect is to alter the marginal physical pro-duct of *C* in the production of Y. Whether this effect is positive or negative is unclear. While studies do indicate that governmental R&D and self-financed R&D may be complements, it is not clear whether this stems from the nature of the production function or from some other source(s). Hence, we place no assumptions on $\partial^2 Y/\partial C\,\partial G$. If empirical work reveals eqn. (11) to be negative, little insight will be gained; however, if eqn. (II) is positive, we will have evidence that *C* and *G* are indeed complements in the production of technical knowledge.

The effect of a rise in self-financed R&D on the optimal degree of sharing is also theoretically ambiguous:

$$\frac{d\,MRP_\alpha}{dC} = \overset{(-)}{\frac{\partial^2 R}{\partial\alpha\,\partial Y}}\;\overset{(+)}{\frac{\partial Y}{\partial C}} + \overset{(-)}{\frac{\partial^2 R}{\partial Y^2}}\;\overset{(+)}{\frac{\partial Y}{\partial C}}\;\overset{(+)}{\frac{\partial Y}{\partial \alpha}} + \overset{(+)}{\frac{\partial R}{\partial Y}}\;\overset{(+)}{\frac{\partial^2 Y}{\partial\alpha\,\partial C}} \gtrless 0 \quad (12)$$

On the one hand, greater *C* reduces the marginal value of α in producing revenues through its increase in the level of Y *(C* affects *R* by way of Y and therefore feeds back to α both directly and indirectly through *Y*). On the other hand, an increase in *C* enhances the marginal physical product of α in the production of *Y*. It is an empirical issue as to which effect is the stronger.

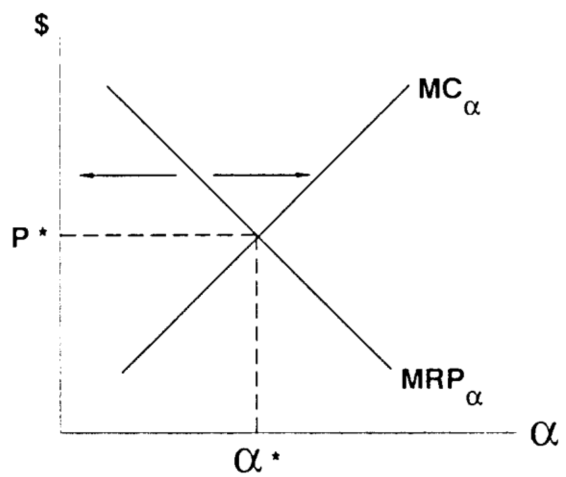

Fig. 3. Determination of optimal sharing. Note: $MRP_\alpha = \partial R/\partial\alpha + (\partial R/\partial Y)\partial Y/\partial\alpha$ and $MC_\alpha = \partial A/\partial\alpha$.

Finally, a rise in governmental R&D contracts/grants affects the optimal degree of sharing in a manner reminiscent of its effect on self-financed R&D:

$$\frac{d\,MRP_\alpha}{dG} = \overset{(-)}{\frac{\partial^2 R}{\partial\alpha\,\partial Y}}\;\overset{(+)}{\frac{\partial Y}{\partial G}} + \overset{(-)}{\frac{\partial^2 R}{\partial Y^2}}\;\overset{(+)}{\frac{\partial Y}{\partial G}}\;\overset{(+)}{\frac{\partial Y}{\partial \alpha}} + \overset{(+)}{\frac{\partial R}{\partial Y}}\;\overset{(?)}{\frac{\partial^2 Y}{\partial\alpha\,\partial G}} \gtrless 0 \quad (13)$$

With a rise in *G*, the marginal revenue product of α falls due to the increased level of *Y*. However, a rise in *G* will also affect the marginal physical product of α in the production of *Y*. The sign of this effect is unspecified. If the sign of the inequality in eqn. (13) is determined to be positive, we will have evidence that α and *G* are complements in the production of technical knowledge.

3. THE EMPIRICAL ANALYSIS

The data used to test the stochastic version of the structural model described by eqns. (9) come from an extensive survey conducted for the National Science Foundation in 1987 on R&D laboratory activity.[3] For this study, detailed information was obtained from 120 corporate (central) laboratories associated with 120 firms in the U.S. manufacturing sector. The key variables estimated are *G*, *C* and α. The amount of R&D that each laboratory receives from the government *G* and the laboratory's own R&D budget *C* are data items in the survey. Each is measured in millions of dollars and relates to each laboratory's 1987 budget.

The degree of sharing associated with the R&D output of each laboratory α is approximated by the percentage of R&D person hours devoted to activities having public good characteristics. As part of the survey, each laboratory was asked to quantify its R&D output by distributing the total number of person-hours among each of the following activities:

- published articles and books
- patents and licenses
- algorithms and software
- internal technical and scientific reports
- prototype devices and materials
- papers for presentation at external conferences
- demonstration of technological devices
- other products

The responses from each laboratory sum to 100, by definition. We define α to be the percentage of each laboratory's time devoted to published articles and books, and to papers for presentation at external conferences. These two broad categories reflect output activities that correspond to our concept of shared knowledge. Of course, a case can be made that most of the output categorized above becomes public over time. For example, it is possible, over time, to decode software or to reverse engineer prototype devices. We do not consider this in our static model.

The regression model that corresponds to the theoretical model in eqns. (9) is:

$$G = \beta_0 + \beta_1 C + \beta_2 \alpha + \beta_3 T + \beta_4 \mathrm{AO} + \beta_5 \mathrm{GE} + \beta_6 \mathrm{LA} + \varepsilon_G \quad (14)$$

$$C = \gamma_0 + \gamma_1 \alpha + \gamma_2 G + \gamma_3 S + \gamma_4 I + \varepsilon_C \quad (15)$$

$$\alpha = \zeta_0 + \zeta_1 C + \zeta_2 G + \zeta_3 \mathrm{BL} + \zeta_4 \mathrm{EL} + \varepsilon_\alpha \quad (16)$$

where the error terms are assumed to be normally and independently distributed.

As is apparent in eqns. (14), (15) and (16), several control variables not included in the theoretical model have been added. The variables *T* and AO are included in eqn.(14) to proxy political-related variables thought to influence the allocation of government R&D. *T* is a binary variable equalling unity if the corporate R&D laboratory had a member of its management or scientific staff testify before a federal legislative body during 1986 as a means of supporting a budget or program request, and zero otherwise. *AO* is also a binary variable equalling unity if the corporate R&D laboratory (or its parent firm) maintains a governmental affairs office, and zero otherwise. Pt is hypothesized that these corporate efforts are undertaken in part, to increase the probability of the firm receiving increased governmental funds, R&D funds in particular. The extent to which these efforts are successful will be seen by $\beta_3 > 0$ and $\beta_4 > O$.

The variable GE is included in eqn. (14) to capture the government's ability to monitor each laboratory's activities. In this sense, GE may also proxy the national interest of the laboratory's work. GE is a binary variable equalling unity if an external governmental agency is responsible for the systematic evaluation of the laboratory and its major programs, and zero otherwise. To the extent that the ability to monitor research increases the government's willingness to allocate R&D dollars, then $\beta_5 > O$.

Finally, we control for each laboratory's history of being involved in activities conducive to inter-laboratory transfers of technical knowledge. LA equals unity if the laboratory has inter-corporate laboratory cooperative research arrangements in place, and zero otherwise. Link and Bauer [21 show that cooperative research arrangements tend to favor basic research, and the results from basic research are more easily transferred among those cooperating. $\beta_6 > 0$ is therefore not inconsistent with the view that governmental funds are allocated to increase innovative efficiency.

Two additional variables are included in eqn. (15). *S* represents size, as measured by the total number of personnel in each R&D laboratory. This variable is intended to control for scale economies in conducting privately-financed R&D. Based on previous empirical studies, we believe $\gamma_1 > 0$.[4] The use, and hence the level of R&D as a strategy variable varies from industry to industry.[5] Thus, we also include in eqn. (15) the variable *I* to control for possible industry differences in the level of R&D spending within R&D laboratories. *I* equals unity if the R&D laboratory's principle research area corresponds to an R&D-intensive industry, and zero otherwise.[6]

In eqn. (16) we control for the research focus of each laboratory. Pt may be the case that laboratories with a particular research focus are oriented toward particular R&D output activities. Our survey data allow us to distinguish two broadly defined sets of laboratories. BL equals unity if the laboratory is oriented toward biological or chemical research, and zero otherwise. EL equals unity if the laboratory is oriented toward engineering research, and zero otherwise.[7]

Descriptive statistics on all of the variables are reported in Table I. This sample of 120 *laboratories* has a private R&D to governmental R&D ratio (based on means) of 6.6I—a very similar ratio as in *firms* within the manufacturing sector as a whole [8].

TABLE 1. Descriptive statistics for the variables ($n = 120$)

Variable	Mean	Standard deviation	Range
C ($M)	8.26	24.87	2 - 202
α (%)	7.47	7.54	0 - 40
G ($M)	1.25	1.91	0 - 16.5
T	0.08	0.28	0 or 1
AO	0.44	0.50	0 or 1
GE	0.11	0.31	0 or 1
LA	0.51	0.50	0 or 1
S	133.76	167.95	6 - 1000
I	0.64	0.48	0 or 1
BL	0.43	0.50	0 or 1
EL	0.68	0.47	0 or 1

Key: *C*, a laboratory's self-financed R&D budget; α, percentage of R&D person-hours devoted to activities having public good characteristics; *G*, a laboratory's governmentally-financed R&D budget; *T*, 1 if the R&D laboratory had a member of its management or scientific staff testify before a governmental legislative body as a means of supporting a budget or program request, and 0 otherwise; AO, 1 if the R&D laboratory (or its parent firm) maintains a governmental affairs office, and 0 otherwise; GE, 1 if an external governmental agency is responsible for the evaluation of the laboratory and its major programs, and 0 otherwise.

It is interesting to note that among these *laboratories* the private R&D to size ratio (based on means) is 0.062, nearly twice that when manufacturing *firm* data are examined. One additional observation is interesting: 44% of these laboratories maintain a governmental affairs office, perhaps reflecting the R&D budgetary importance of governmental funds.

Equations (14), (15) and (16) were estimated simultaneously. The three-stage least-squares results are reported in Table 2. In general, the empirical results support our hypotheses.

Regarding eqn. (14), inter-laboratory differences in governmental R&D allocations are systematically related to the scale of the laboratory's own R&D efforts and to the extent to which the laboratory's R&D output is shared. Both estimated coefficients are positive, although only the coefficient on C is significant at a conventional level. Certain corporate efforts to remain visible in the governmental funding arena have a positive influence on *G*. The significance of the coefficient on *T* suggests that visibility gained through legislative testimony is an important factor that influences governmental allocations. None of the other control variables is significant although the positive coefficient on LA is not inconsistent with an efficient view of government allocations.

Turning to eqn. (15), we found the coefficient on α to be negative and significant. Given our discussion in Section 2, this result seems to indicate that while added sharing may increase the marginal physical product of self-financed R&D in producing laboratory output, the loss due to a lower competitive advantage is the dominating influence. Additionally, we find, unlike others, an insignificant (although positive) partial correlation between self-financed and governmentally-financed R&D. Given our discussion in Section 2, this would seem to provide weak statistical evidence for C and *G* being complements in the production of technical knowledge. Perhaps the positive and significant relationship between private and governmental R&D from others' single equation models misrepresents the manner in which govern-mental funding influences private R&D decisions by ignoring the possibility that governmental allocations can simultaneously impact the scope and type of research undertaken. Interestingly, when eqn. (15) is estimated alone using ordinary least squares, the estimated coefficient on *G* is positive and significant, as others have reported. The results in eqn. (15) do support the proposition that size *per se* is an important determinant of the level of internal R&D spending. Finally, we find no industry effect on the distribution of *C* among laboratories. This was also the case when separate industry dummy variables were included in an alternative version of eqn. (15).

TABLE 2. Three-stage least squares estimates of eqns. (14), (15) and (16) (asymptotic *t*-statistics reported in parentheses)

Equation (14)

$$G = -0.02 + 0.03C + 0.10\alpha + 1.69T - 0.03AO - 0.07GE + 0.36LA$$
$$\quad (-0.04) \quad (2.75) \quad (1.30) \quad (2.33) \; (-0.09) \quad (-0.10) \quad (0.90)$$

Equation (15)

$$C = 3.09 - 1.60\alpha + 4.57G + 0.08S + 2.95I$$
$$\quad (0.51)(-1.66) \quad (1.19) \quad (3.78) \quad (0.58)$$

Equation (16)

$$\alpha = 4.85 - 0.14C + 2.39G + 0.12BL + 1.21EL$$
$$\quad (2.71)(-2.24) \quad (1.98) \quad (0.09) \quad (0.81)$$

System weighted $R^2 = 0.25$

Note: To determine the statistical merits of three-stage least squares we follow Belsley [9]. Belsley suggests that "it would seem safe to say that 3SLS would possess good small-sample relative efficiency [relative to 2SLS] for values of λ_{min} and det(**R**) in the neighborhood of 0.1 and for values of $\varkappa(\mathbf{R})$ above 20–30" (p. 28). Here, the determinate of the cross-equation correlation matrix, det(**R**), is 0.73 and the minimum eigenvalue of **R**, λ_{min}, is 0.51. $\varkappa(\mathbf{R})$ is the ratio of the maximum eigenvalue to the minimum eigenvalue of **R**, and it is 3.11. Thus, is appears that only a minimum degree of efficiency is gained from going from 2SLS to 3SLS. The 2SLS results are similar to the 3SLS results with only one exception. The most notable change is that $\partial C/\partial\alpha$ reduces in significance in eqn. (15). The 2SLS results are available upon request. Also, an inspection of Table 1 indicates that the variables α and *G* are truncated at 0. Five observations account for these values. Because the estimate results are unchanged when these observations are deleted, the maintained assumptions about the error terms associated with the empirical model appear valid.

With respect to eqn. (16), the estimated coefficient on C is significantly negative. This finding confirms the notion that while self-financed R&D and knowledge sharing may act synergistically in the production of laboratory output, the dominant effect of greater own R&D is to decrease the marginal revenue product associated with greater laboratory output. We also found the coefficient on *G* to be significantly positive, thus indicating α and *G* are complements in the production of technical knowledge. This latter result is not inconsistent with a view that government allocates its R&D resources in such a way as to increase social welfare by increasing public knowledge *per se.* Surprisingly, the composition of R&D output does not vary, *ceteris paribus,* across laboratories according to their primary field of research. The estimated coefficients on both BL and EL are insignificant.

4. CONCLUDING OBSERVATIONS

The results presented in this paper suggest that governmental R&D con-tracts/grants allocations to industrial firms have a broader impact on corporate (laboratory) performance than previously discussed in the relevant literature. The dominating influence of governmental R&D is not to stimulate the level of private R&D spending (although this happens to some degree), but rather to affect the predilections for sharing private research results. While this conclusion must be treated with caution owing to the limitations of the data, our efforts nonetheless represent the first empirical attempt to examine the breadth of possible influence that governmental R&D funding has on private R&D activity. Thus, it is intended that this inquiry will open the door for future research leading to a more complete understanding of the scope of governmental influence on private innovative behavior.

Such understanding is particularly important in the face of recent efforts in the U.S.A., and in other industrialized nations, to increase public domain research. Our analysis, while preliminary, suggests that additional work is warranted before policy makers retreat in full from direct governmental support through contracts and grants to industry.

NOTES

[1] For a critical review of governmental R&D-related initiatives, see Bozeman and Link [1]. For an overview of the economic implications of cooperative R&D activity, see Link and Bauer [2].
[2] For a review of the early literature on this topic, see Link [4]. See Lichtenberg [5] for a more recent study as well as for a critical evaluation of econometric issues related to the previous studies.
[3] See Bozeman and Crow [7] for a complete documentation of this broader study.
[4] These studies are summarized in Link [4] and Lichtenberg [5].
[5] See Link and Tassey [8].
[6] R&D intensive industries are defined by us, based on NSF reported R&D-to-sales ratios, to be chemicals, petroleum refining, non-electrical machinery, electric and electronic equipment, transportation equipment and instruments.
[7] These binary variables equal unity if the laboratory has more than 25% of its scientific and technical personnel in the relevant research area. The critical value of 2507o is subjective, being determined by us from a series of personnel interviews with laboratory representatives. These are not mutually exclusive categories.

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Les effets du financement gouvernemental sur les activites de recherche et développement des sociétés: une enquete théorique et empirique

RÉSUMÉ

Aux Etats Unis le gouvernement prête son soutien depuis longtemps à l'activité privée innovative. Cependant la recherche économique dans ce domaine s'est essentiellement concentrée sur les liens entre le niveau de recherche et développement gouvernemental et le niveau correspondant (au sens causal) de recherche et dével-oppement privé. Cet exposé examine les effets du financement gouvernemental sur un autre aspect du comportement innovatif privé—le partage entre sociétés de leur connaissances en matiére d'innovations. En nous basant sur un simple modéle d'activité innovative en face d'une structure gouvernementale exogene de contrats/subventions pour la recherche et le developpement, nous nous rendons compte en particulier que les allocations gouvernementales pour la recherche et le developpement incitent les laboratoires de recherche et developpement industriels partager plus souvent leurs connaissances en matiere d'innovations.

Die Auswirkungen der Subventionen von Seiten der Regierung auf die Unternehmerischen Forschungs- und Entvvicklungsaktivitaten: eine Theoretische und Empirische Untersuchung

ABRISS

Schon seit vielen Jahren untersttitzt die Regierung die privaten, innovativen Aktivitaten in den U.S.A. Die wirtschaftlichen Nachforsehungen zu diesem Thema waren bisher jedoch kurzsichtig und betonten hauptsachlich das Verhaltnis zwischen dem Ausmafi der von seiten der Regierung getatigten Forschung und Entwicklung Lind dem (im kausalen Sinne) entsprechenden Ausmaβ der privaten Forschung und Entwicklung. In dieser Abhandlung untersuchen wir die Auswirkungen der Offentlichen Finanzierung auf einen anderen Aspekt des privaten innovativen Verhaltens—namlich die Tatsache, daβ Unternehinen ihr innovationsbezogenes Wissen teilen. Ausgehend von einem einfachen Modell, bei den) die private, innovative Aktivitat einer exogenen Struktur, gekennzeichnet durch Forschungs- und Entwicklungsvertrage/subventionen von seiten der Regierung, gegennbersteht, bemerken wir unter anderem, daβ die öffentlichen Zuwendungen die industriellen Forschungs- und Entwicklungslaboratorien in höherem Maβe dazu anregen, ihr innovationsbezogenes Wissen untereinander zu (ellen.

Los efectos de la financiaciòn gubernamental en los programas de investigacion y desarollo de empresas: una investigacion teoretica y empirica

RESUMEN

Hay una larga historia de apoyo gubernamental en los Estados Unidos para actividades innovadoras privadas. Sin embargo, la investigacion economica en este campo ha tenido un enfoque limitado, destacando sobre todo la relacion entre el nivel de investigacion y desarollo gubernamental y el nivel correspondiente (por causa) de investigaciOn y desarollo privado. Este documento examina los efectos de la financiacion gubernamental en otro aspecto del comportamiento privado inovador—el compartir entre empresas conocimientos relacionados con la innovacion. Basado en un modelo sencillo de actividad privada a vistas de una estructura exogena de contratos/subvenciones gubernamentales para investigacion y desarollo, descubrimos que, entre otras cosas, las aportaciones gubernarnentales para investigacion y desarollo impulsan a los laboratorios de investigacion y desarollo a compartir cada vez mas sus conocimientos relacionados con la innovacion.