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Public R&D Policies and Cost Behavior of the US Manufacturing Industries

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Abstract

This paper estimates and evaluates the contributions of R&D tax incentives and publicly financed R&D investment policies in promoting growth of output and privately funded R&D investment in US manufacturing industries. Publicly financed R&D induces cost savings but crowds out privately-financed R&D investment while the incremental R&D tax credit and immediate deductibility provision of R&D expenditures have a significant impact on privately financed R&D investment. The optimal mix of both instruments is an important element for sustaining a balance growth in output and productivity in manufacturing sector.

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Introduction*

An important characteristic of R&D investment which distinguishes it from other types of investment is that its output has the properties of public goods: It can be considered at least partially non-excludable and non-rivalrous (see Arrow (1962), Spence (1984), and Romer (1990)). Indeed, the empirical literature provides evidence that not only is the rate of return of privately-funded R&D very high compared to that of investment in physical capital, but, more importantly, its social rate of return is several times higher than its private rate of return (see, for instance, Cohen and Levin (1989), Griliches (1979, 1991), Mohnen (1989, 1990) and Nadiri (1980, 1993)). This suggests that there are substantial externalities associated with R&D investment, and therefore privately-financed R&D is suboptimal and may require the direct or indirect support of government.

Theoretically, there are many different ways to deal with market failure associated with externalities.[1] For instance, externality-generating activities can be encouraged by providing subsidies, by granting producers property rights and charging differential prices for their use by others, by allowing firms to internalize the externality and, finally, by having the government engage directly in externality-generating activity. Indeed, in the postwar period, the US government has followed a combination of these policies: establishment of innovators' property rights through the patent system, encouragement of firms to form joint R&D ventures, direct investment of R&D through R&D contracts with companies, universities and other nonprofit institutions, and lastly, tax incentives for company-financed R&D.

The objective of this paper is to evaluate the contributions of tax incentives and public financing of R&D investment policies in promoting growth of output and productivity of the US manufacturing industries. First, we provide econometric evidence of the effects of R&D tax policies in stimulating privately-funded R&D.[2] We are particularly interested in calculating the effect of R&D tax credit and of treating R&D expenditures as an operating expense rather than a capital expenditure. To put it differently, we are interested in measuring how much private R&D investment would have fallen if the R&D tax credit were abolished and if R&D expenditures were treated as capital expenditures similar to the expenditure on plant and equipment. Second, we investigate the existence and extent of the spillover effects of publicly-funded R&D capital on the cost structure of manufacturing industries at a disaggregated level. A number of studies have examined the effect of industry-specific, publicly-financed R&D granted to firms in specific industries. The empirical results have been thus far inconclusive.[3] In contrast, however, we are interested in evaluating the effect of total R&D undertaken by the public sector on the growth and productivity of specific industries. This type of spillover effect of publicly-financed R&D has not, to our knowledge, yet been studied. Finally, we evaluate these policies by estimating (i) a social benefit-cost ratio of publicly-financed R&D, and (ii) the additional privately-funded R&D expenditures generated by the R&D tax policies relative to the foregone government tax revenues.

To achieve these objectives, we estimate a cost function dual to a production function where, except for the traditional inputs, the rental price of company-financed R&D capital, and the capital of publicly-financed R&D explicitly enter into the cost function. Our results suggest that, on the one hand, publicly-financed R&D induces cost savings but crowds privately-financed R&D investment. On the other hand, the incremental R&D tax credit introduced in 1981 and the immediate deductibility provision of R&D expenditures, especially the latter, have a substantial inducement effect on private R&D expenditures in the manufacturing sector.

The Model and Empirical Implementation

The theoretical basis of our model is the standard neoclassical production function augmented to include two R&D capital stocks, one financed by the industry and the other publicly financed, which may capture potential spillover benefits from government-financed R&D activity. We assume that firms within an industry minimize their post-tax cost of production subject to the production function, and that publicly-financed R&D is an unpaid input of production. A typical post-tax cost function of an industry at time t is given by

$$C = C\ (p,\ y,\ G;\ t), \tag{1}$$

where p is a vector of the after-tax rental price of inputs, y is the industry's output, and G is the aggregate government-financed R&D capital.

To estimate the productive effects of government's R&D tax policy, we need to know the elasticity of company-financed R&D with respect to its own price, and the cross-price elasticities of all other inputs with respect to the price of R&D, as well as the effect of tax incentive on the after-tax rental price of company-financed R&D. A nice feature of duality theory is that the second derivatives of cost function with respect to input prices, i.e., the Bordered Hessian matrix $C_{ij} = (\partial^2 C/\partial p_i p_j)$, correspond to the input demand price derivatives (see Diewert (1974) or Varian (1984)). The effect of tax incentives on the input demands can therefore be calculated in a straightforward manner by estimating a cost function like (1), and by knowing the effect of tax incentives on the rental price of company-financed R&D.

In addition, the effect of publicly-financed R&D can be estimated by observing that its derivative of cost, $\partial C/\partial G$ ($\neq 0$), corresponds to the cost change due to an additional unit of public R&D. If the sign is negative, a positive externality exists, while a positive sign indicates the existence of a negative externality. The marginal benefit or marginal willingness to pay function of an industry can be defined as

$$b(w, y, G) = - \partial C/\partial G. \tag{2}$$

This is the benefit, in terms of cost reduction, gained by an industry due to an increase of a unit of government-financed R&D capital (see Diewert (1986)).

In order to measure the effects of government's tax policy, and of publicly-financed R&D on the cost structure of US manufacturing industries at the two-digit level, we specify a generalized Cobb-Douglas cost function analogous to Schankerman and Nadiri (1986) and Nadiri and Mamuneas (1991). It is also assumed that industry h employs four private inputs, namely labor, intermediate inputs, physical capital (structures plus equipment), and company-financed R&D capital, and that the publicly-financed R&D services entering in the production function of the industry in question are proportional to the R&D capital financed by the government.

The unit post-tax cost function is given by

$$\begin{aligned} \ln C^h/p_m^h - \ln Y^h &= \\ &= \beta_0 + \alpha_0^h D^h + \textstyle\sum_i (\beta_i + \alpha_i^h D^h) \ln w_i^h + \beta_t t \\ &+ \textstyle\sum_i \sum_j \beta_{ij} \ln w_i^h \ln w_j^h + \sum_j \beta_{it} \ln w_i^h t \\ &+ [\phi_s + \gamma_s^h D^h + \phi_{is} \ln w_i^h + \phi_{ts} t] \ln G, \end{aligned} \tag{3}$$

$$i \neq j = L,K,R; \quad h = 1,..,n,$$

where C, w, Y, t, G , D, denote, respectively, total production cost ($C = \sum p_j x_j$), the vector of relative input prices with respect to the price of materials, p_M ($w_i = p_i/p_M$), output, a time shift variable representing exogenous technological change or other time-specific effects experienced by the industries, the aggregate publicly-financed R&D capital, and a set of dummy variables capturing industry specific effects. The subscripts i and j denote the own inputs, and h the industries. Also, the subscripts M, L, K, R, denote, respectively, the intermediate inputs, labor, physical capital, and the industries' privately-financed R&D capital. The parameters ϕ capture the externalities generated from the public R&D capital. The existence of parameters α and γ enables us to capture industry specific effects as deviations from the β and ϕ parameters. The coefficients of the dummy variables have been normalized such that for the industry n, $\alpha_n = \gamma_n = 0$. Note that the specified cost function (3) implies constant returns to scale in terms of private inputs, but increasing returns to scale in terms of all inputs including publicly financed R&D.[4]

Applying Shephard's lemma (Diewert (1974)), the following share equations are obtained:

$$S_i^h = \beta_i + \alpha_i^h D^h + \beta_{ij} \ln w_j^h + \beta_{it} t + \phi_{is} \ln G, \qquad (4)$$

$$i = L,K,R; \quad h = 1,..,n,$$

where $S_i^h = p_i^h x_i^h / C^h$. The share of the input used for the normalization is calculated by $S_M^h = 1 - \sum_i S_i^h$. Shares are affected by publicly-financed R&D capital and the parameter ϕ_{is} determines the factor bias effect associated with the publicly-financed R&D capital in each industry.

The Hessian matrix ($\partial^2C/\partial p_i \partial p_j$) should be negative semi-definite in order for the cost function to be concave in input prices. In addition, for the cost function to be convex in G, $\partial^2C/\partial G^2$ should be non-negative. Note that in order for the technology set to be convex, all of the above conditions should be satisfied (see Diewert (1986)). Furthermore, in order for the spillovers to have a meaningful context, the cost function should be non-increasing in G. Finally, the cost function must be non-decreasing in output, and linear homogeneous in input prices (see Jorgenson (1984)). The last condition is automatically satisfied, since we have normalized with the price of intermediate inputs.

The model is applied in a sample of twelve manufacturing industries, plus three industries which were aggregated because of data limitation. The estimation period covers the years 1956 to 1988. The sample covers all industries of the manufacturing sector, which are reported in table 1. A detailed description and construction of the variables of the model are reported in appendix A. Assuming that the errors attached to equations (3) and (4) are optimizing errors, they are jointly normally distributed with zero expected value, and with a positive definite symmetric covariance matrix. The data on industries are pooled and the estimation is carried out with the full information maximum likelihood estimator.

Our estimation results are reported in table 2. The individual parameter estimates have a high t-statistic, and R^2 of the estimating equations are high. The standard errors of the regressions are quite low, indicating a good fit. The parameters associated with government-financed R&D capital are statistically significant, which implies that there are indeed spillovers associated with publicly-funded R&D capital. In addition, the coefficients of industry dummy variables (not reported) were also jointly statistically significant, implying interindustry differences in technology (see rows 6 to 9 in table 3).

A number of hypothesis tests have been performed in order to accept the above specification. First we tested whether the production technology across industries is the same. We set the pooling parameters to zero and reestimated the model without industry-specific dummies. The chi-square statistic reported in the first row of table 3 indicates that this hypothesis is decisively rejected. Further, we tested whether industries have the same technology only for the private inputs or whether they have different technologies in terms of private inputs, but there are no technological differences in terms of spillover. These hypotheses are also rejected as indicated by the chi-square statistics of the second and third row of table 3.

Another important hypothesis which we tested is whether the cost function is independent of publicly-financed R&D. To test this hypothesis, we reestimated the model by setting the "spillover" parameters equal to zero. The log of likelihood function as well the chi-square statistic of this test is reported in the fourth row of table 3. This hypothesis was also decisively rejected. Finally, the hypothesis that industries do not experience exogenous technological shocks was tested and clearly rejected (see table 3, fifth row).

The Effects of R&D Tax Policy on Cost Structure

The federal government, recognizing the importance of R&D investment for economic growth and international competitiveness, has historically treated R&D investment more favorably than other kinds of investments. The federal government basically uses two kinds of tax policy instruments to stimulate R&D

expenditures. One, in place since 1954, is the immediate deductibility provision of company-financed R&D expenditures, and the other is the direct R&D tax credit introduced by the Economic Recovery Tax Act (ERTA) of 1981. The ERTA, in addition to the introduction of the Accelerated Recovery System (ARCS) for investment in plant and equipment, introduced an incremental R&D tax credit for qualified research expenditures. Firms were eligible to claim either 25% credit if their R&D expenditures exceeded the average of R&D spending of the three previous years or half of the credit if they were above twice the base. This credit was initially intended to expire at the end of 1985, but was renewed at a rate of 20% for two additional years in the Tax Reform Act of 1986 (TRA).[5]

In order to see the effect of these two R&D tax incentives on the price of R&D, assume that a firm incurs $1 of R&D expenditures in excess of its R&D expenditures in the past three years. With an incremental tax credit of 25%, this means that the cost to the firm will be reduced by $1 x .25=$.25. However, the $1 increase in R&D expenditures decreases the incremental R&D tax credit for the next three years by $.33 x .25 = $.083 for each year. Thus with a discount rate of 10% the net tax reduction of a $1 increase in R&D expenditures is $\$.25 - (\sum_{i=1}^{3} \$.083 / (1 + .10)^i) = .045\$$, and the actual post-tax cost of the expenditures is $1 - $.045 = $.955.

Consider now the effect of the immediate deductibility provision of R&D expenditures. Suppose that the corporate income tax rate is 46%; then the tax reduction is $.46, and the after-tax cost of R&D expenditures $1 - $.46 = $.54. Combining these two incentives, the after-tax cost of $1 of R&D expenditures is $1 - $.46 - $.045= $.495, i.e., about 50% less than its before tax cost.

In order for the firms to benefit from the tax incentives, they must have sufficient taxable income. In addition, in the case of incremental R&D tax, Eisner et. al (1984) have estimated that in 1981 and 1982 about 25% and 35%, respectively, of the firms in the manufacturing sector did not claim the incremental R&D tax credit either because they did not increase their R&D expenditures over the base or they did not have sufficient federal income tax liabilities. Also note that the incremental character of the credit in some cases might even make the effective rate negative (see, Eisner et al. (1984) and Hall (1992)). In the absence of information, we assume that the firms in our sample of industries have enough tax liabilities, and that the increase of their R&D expenditures was greater than the base but less than twice the base.

Under the above assumptions, let u_c be the corporate income tax rate, ζ the incremental R&D tax credit, and λ a parameter taking values of 1 if there is immediate expensing of R&D expenditures, but values less than 1 otherwise.[6] The after-tax cost of R&D expenditures is given by $q_R\ (1 - \lambda\ u_c - \nu\ \zeta)$, where q_R is the acquisition price, $\nu = (1 - \sum_{i=1}^{3} .33/(1+r)^i)$ and r is the discount rate.[7] Table 4 shows the after-tax cost of $1 R&D expenditures for the period 1981 to 1988. The average after-tax cost of $1 R&D expenditures for this period is about $.55, where the contributions of immediate expensing and the incremental R&D tax credit are about .42 and .038 respectively.

Changes in R&D tax incentives affect the rental price of R&D capital and, consequently, the level of R&D capital. The change in the level of R&D capital determines in turn the additional R&D expenditures. Let the after-tax rental price of R&D capital services (p_R) be defined by the equality between the post-tax cost of acquisition and the present value of future rentals (see for instance Hall and Jorgenson (1967)), then the post-tax rental price of company-financed R&D capital is given by

$$p_R = q_R\ (r+\delta_R)(1 - \lambda\ u_c - \nu\ \zeta), \tag{5}$$

where q_R is the acquisition price, r is the discount rate and δ_R is the depreciation rate of company-financed R&D capital. For a given level of output, the effect of a change in tax incentives (T) on the demand of R&D capital stock and on the other inputs is given by

$$\eta^h_{jT} = \partial \ln x_j\ /\ \partial \ln T = \epsilon^h_{jR}\ (\partial \ln p_R\ /\ \partial \ln T) \tag{6}$$

$$T = \zeta,\ \lambda$$
$$j = L,\ K,\ R,\ M,$$

where ϵ^h_{jR} is the price elasticity of input demands with respect to the rental price of R&D capital and $(\partial \ln p_R\ /\ \partial \ln T)$ is the elasticity of the rental price of R&D capital with respect to a change in tax incentives and is equal to either

$$\partial \ln p_R\ /\ \partial \ln \zeta = -\nu\ \zeta\ /\ (1 - \lambda\ u_c - \nu\ \zeta)$$

for a change in incremental R&D credit or

$$\partial \ln p_R\ /\ \partial \ln \lambda = -\ \lambda\ u_c\ /\ (1 - \lambda\ u_c - \nu\ \zeta)$$

for a change in immediate expensing.

The conditional input demand price elasticities are reported in table 5. The price elasticities of the input demands are calculated by $\epsilon^h_{ij} = s^h_j\ \sigma^h_{ij}$, where σ_{ij} are the Allen elasticities of substitution and under our cost function specification are equal to $\sigma^h_{ij} = (\beta_{ij} + s^h_i\ s^h_j)\ /\ s^h_i\ s^h_j$ and $\sigma^h_{ii} = (s^{h2}_i - s^h_i)\ /\ s^{h2}_i$. The diagonal elements in each panel of industries correspond to own price elasticities. One obvious pattern that emerges from this table is that the own price elasticities of labor, physical capital and intermediate inputs vary from one industry to another. Conversely, the own price elasticity of company-financed R&D capital does not vary much from industry to industry.[8] The own price elasticity of private R&D capital ranges from -1 in the three aggregates textile and apparel (40), lumber, wood products and furniture (41) and other manufacturing (42) to -0.94 in scientific instruments (38). The company-financed R&D elasticity estimated in this study is in the middle range of own price elasticities of R&D reported in the literature. Hines (1991) has estimated a price elasticity of company-financed R&D about -1.2, Hall (1992) about -1, while Nadiri and Prucha (1989), Bernstein and Nadiri (1989) have reported a price elasticity of total R&D (company- plus publicly-financed) of about -0.4 to -0.5. Our estimates are closer to Hall (1992) and Hines's (1991). The difference between our estimates of own price elasticity of company-financed R&D and the estimates of Bernstein and Nadiri and Nadiri and Prucha can be explained by the fact that the elasticities estimated by those authors pertain to total R&D performed by the industry, ie., company-financed as well as publicly-financed, and thus respond less to price changes.

Another interesting observation that emerges from table 5 is that company-financed R&D capital and physical capital are substitutes. In high R&D intensive industries, however, this relation is very weak. It also seems that a change in the price of company-financed R&D affects physical capital relatively less than a change in the price of physical capital affects company-financed R&D capital. This has a very important implication for public policy since the tax policy for structures and equipment will have significant indirect effects on the R&D investment. Cordes (1984), for instance, has argued that the Accelerated Recovery System, introduced in 1981 for plant and equipment investment, has moved the relative price of physical capital to R&D capital in favor of the former. Thus the introduction of an incremental R&D tax credit was necessary to restore to some degree the incentives for R&D investment. The current administration's proposed reintroduction of investment tax credit, if it passes, may have a negative effect on company-financed R&D investment provided there is not a simultaneous increase in support for R&D. Finally, while company-financed R&D is a substitute for labor, it is a complement of intermediate inputs in low R&D intensive industries, but a weak substitute in high-tech industries, such as chemical (28), machinery (35), electrical equipment (36), transportation equipment (37), and scientific instruments (38).

The average (for the period 1981 to 1988) elasticities of cost, labor, physical capital, R&D capital and intermediate inputs with respect to incremental R&D tax credit are reported in table 6.[9] This table has been constructed by multiplying the input price elasticities by the percentage change of rental R&D price due to a change in the incremental R&D tax credit. Similarly, constructing table 7 gives the average elasticities of the cost and input demands with respect to the rate of immediate expensing of R&D expenditures. Both effects are relatively larger in the low R&D intensive industries than in high-tech industries, reflecting the fact that industries with a long tradition of R&D investment respond less to the cost changes of R&D investment This is consistent with the evidence from the tax forms of 1981, 1982 and 1983, (see Cordes (1988, 1989)) showing that, after the introduction of R&D tax credit, the high-tech manufacturing industries reported smaller increases in the R&D expenditures than the other manufacturing industries.

Clearly, a change in the rate of expensing has a larger effect than a change in incremental R&D tax credit. This is because the immediate deduction of R&D expenditures constitutes about 90% to 96% of the reduction of the cost of R&D, while the incremental R&D tax credit constitutes the rest. The effect of the incremental R&D tax credit is small but nevertheless significant. Based on our estimates, the incremental R&D tax credit had generated about $2.5 billion dollars (on average) of additional R&D expenditures per year at the manufacturing sector for the period 1981 1988. This estimate is consistent with that reported by Baily and Lawrence (1992) and Hall (1992). If it is adjusted with the eligibility ratio of about .63 (see Eisner et al. (1984)), the R&D credit has stimulated about $1.6 billion dollars of additional R&D expenditures per year.[10]

Suppose that the government, instead of allowing the immediate deductibility of R&D investment, allows only the economic depreciation of R&D expenditures to be deducted from current income. With a discount rate and depreciation rate of 10% (see footnote 6), this implies that the value of the parameter λ is .5, and will account on average for a roughly 35% decline of R&D expenditures, or about $16 billion dollars per year for the manufacturing sector as a whole. Combining this estimate with the additional expenditures stimulated the R&D credit, government tax incentives would generate $18 billion dollars per year of additional R&D expenditures. This amounts to approximately 40% of the total privately-financed R&D of the entire manufacturing sector. Moreover, if one takes into account that government directly finances about 30% of total R&D performed in the manufacturing sector, the tremendous support of R&D activity by the federal government is quite clear.

The Effects of Publicly-Funded R&D on the Cost Structure

An increase of publicly-funded R&D has a significant effect on the cost of industries if, as has been discussed, the derivative of cost with respect to publicly-financed R&D is different from zero. Differentiating the cost function with respect to G, the "spillover" elasticity of cost is given by

$$\eta^h_{CG} = \partial \ln C^h \;/\; \partial \ln G = \phi_s + \gamma^h_s D^h + \textstyle\sum_i \phi_{is} \ln w^h_i + \phi_{ts}\, t \qquad (7)$$

$$h = 1,..n.$$

In addition, a change of publicly-financed R&D affects not only the cost function, but also the demand for inputs, given by

$$\eta^h_{jG} = \partial \ln x^h_j \;/\; \partial \ln G = \eta^h_{CG} + (1 \;/\; S^h_j)\, \phi_{is} \qquad (8)$$

$$j = L,K,R,M; \quad h = 1,\ldots,n.$$

If (8) is positive, negative or zero, it implies that the publicly-financed capital and the jth private input are complements, substitutes, or neutral, respectively.

The effects of publicly-financed R&D on the cost and input demands are reported in table 8. Our results support the hypothesis that there is a positive externality from publicly-financed R&D. The effect is significant in all industries in the manufacturing sector except in petroleum refining and related industries (29) and primary metals (33). In terms of magnitude, the cost elasticities with respect to publicly-financed R&D capital vary considerably across industries from -.09 for fabricated metals (34) and transportation equipment (37), to -.3 for electrical equipment (36) in the highest range. In all industries the labor input and publicly-financed R&D

capital are substitutes, while publicly-financed R&D capital is complementary with intermediate inputs. The effect of publicly-financed R&D capital on physical capital varies across industries in terms of the magnitude as well as its direction. Publicly-financed R&D and physical capital are weak substitutes in paper and allied products (26), rubber products (30), machinery (35), and electrical equipment (36), while they are weak complements in the rest of the industries of the manufacturing sector.

Our estimates suggest that the spillover effect of publicly-financed R&D reduces the cost to industries and thus enhances their technological opportunities . However, it seems that publicly-financed R&D crowds out company-financed R&D in all industries. Indeed, in low R&D intensive industries the crowding-out effect of publicly-financed R&D is more than one to one, while in high-tech industries publicly and privately-financed R&D are weak substitutes; for instance transportation equipment (37) and scientific instruments (38).

Two hypotheses have been advanced between the relationship of publicly-financed and privately-financed R&D performed by the industries. One supports the idea that new scientific knowledge resulting from government financed R&D expands firms' basic knowledge and thus induces the firms own R&D (Goldberg (1979), Jaffe (1989), Levin and Reiss (1984), Levy and Terleckyj (1983), Link (1982), Nadiri (1980) and Scott (1984)); the other suggests that publicly-financed and company-financed R&D are substitutes, because either the output of public R&D activity is internalized by the firms, or the publicly-financed R&D performed by the firms causes the firms to reach their full R&D capacity (Carmichael (1981), Lichtenberg (1984, 1988) and Nadiri (1980)). Our estimates seem to support the latter hypothesis, especially in the low R&D

intensive industries. One must keep in mind, however, that the concept of publicly-financed R&D used in this study is different from the concept of publicly-funded R&D used in the above-mentioned studies. In these studies, publicly-funded R&D refers to the R&D financed by the government and performed within the industry in question. In this study, publicly-financed R&D refers to the government-financed R&D performed in other industries and non-profit institutions as well as within the industry in question.

For the high-tech industries, however, a more careful interpretation suggests that there are two effects at the level of company-financed R&D. First, in the usual sense, publicly-financed R&D acts as a substitute of company-financed R&D. Second, competition among firms for government R&D contracts leads them to increase private R&D expenditures in order to "signal" their capability to do R&D (Lichtenberg (1988)). Hence, the net crowding out effect is less than that observed for low-tech industries.

The Effectiveness of Publicly-Financed R&D and R&D Tax Policy

The objective of this section is to evaluate the effectiveness of tax policies and the federal government's R&D expenditures. As far as the incremental R&D tax credit is concerned, this can be done by measuring the additional R&D expenditures generated relative to foregone tax revenues. For publicly-financed R&D, this can be done by comparing the social benefits and costs of publicly-financed R&D capital.

There is some disagreement among economists about the effectiveness of R&D tax credit. For instance, Mansfield (1984, 1986) has estimated that the additional R&D expenditures per dollar cost to the government ranges between \$.3 to \$.4. Baily and Lawrence (1992) have estimated it to be about \$1 to

$1.4. About the same estimates as Baily's are provided by Hines (1991), while Hall (1992) estimates that the ratio is about 2. These differences in estimates are basically due to different price elasticities of R&D employed by the authors. Noting that the tax incentives are subsidies to production, for a given output the resulting reduction in industry costs is equal to the loss of government revenue. Thus, we can calculate the ratio of additional R&D capital services over the foregone government revenue by

$$r_{\varsigma} = \sum_h \eta^h_{R\varsigma}\ p^h_R\ x^h_R \ / \sum_h \eta^h_{C\varsigma}\ C^h, \tag{9}$$

where the numerator is the sum of additional R&D capital services over all industries and the denominator is the foregone government revenues. Our estimate implies an average of additional R&D per dollar of government revenue lost to be about .95 for the period 1981 to 1988 for all industries in our sample. Comparing this ratio with the findings of the other literature, our estimate is in the middle range. We can conclude that the R&D tax credit has not been a failure as the early literature on the subject has suggested, but rather that it has had a modest but significant impact in stimulating R&D investment. Moreover, if one takes into account the induced output effect from increases of R&D expenditures, as well as the extent to which there are spillovers from privately-financed R&D (and the empirical literature supports this hypothesis (see for instance, Nadiri (1991)), and company-financed R&D and R&D spillovers are complements, then the benefit-cost ratio of incremental R&D tax credit will be substantially higher.

Turning now to the evaluation of the relative effectiveness of publicly-financed R&D, assume that the social planer's objective is to maximize the producer surpluses generated by publicly-financed R&D. Then the sum of marginal benefit over industries can correspond to a measure of social benefit.[11] This measure, however, is crude, since the effects of publicly-financed R&D capital on the rest of the economy, as well as the benefits of the particular projects for which has been financed, are not taken into account. Nevertheless, the ratio of benefits to cost of an additional unit of publicly-financed R&D is given by

$$r_G = \sum_h -\eta^h_{CG} \ (C^h/G) \ / \ q_G \qquad (10)$$

where the numerator of (10) is the sum of marginal benefits of industries from an additional unit of publicly-financed R&D capital, and the denominator the marginal cost of an additional unit of publicly-financed R&D capital taken to be equal to its acquisition price q_G. Table 8 shows the average marginal benefit for each industry for the sample period. For each additional unit of publicly-funded R&D, industries are willing to pay from -1¢ in primary metals (33) to 5¢ in electrical equipment(36). The sum of marginal benefits is 29¢ for each additional unit of publicly-funded R&D capital, which implies that the rate of return of publicly-funded R&D, calculated using equation (10) is about .5 on average. This suggests that there might be underinvestment of publicly financed R&D, and that government should increase its investment.

In fact, some economists have argued that government should abolish the incremental R&D tax credit because it is ineffective, and instead increase publicly financed R&D expenditures by the amount of revenues saved (Mansfield (1986)). We want to see, if we follow Mansfield's (1986) suggestion, what will be the impact on the industries' production cost and R&D investment in the manufacturing sector. In advance we have to say that, based on the previous discussion, the effect of the two instruments on company-financed R&D

are quite different. The publicly-financed R&D crowds out privately-financed R&D investment, while the R&D tax credit induces it. In table 9 we report the results of the following experiment: First, we assume that for the year 1988 the government abolishes the incremental R&D tax credit and also that it allows only the economic depreciation of R&D expenditures to be deducted from the current income. Given our estimates of tables 6 and 7, these assumptions would imply that the additional cost for the industry or the revenues saved by the government would be about $16.9 billion. Second, we assume that the government increases the publicly financed R&D by the exact amount of revenues saved which represents a 3.6% increase of publicly financed R&D. Using the cost elasticities of table 8, the cost reduction of all industries due to a 3.6% increase of publicly financed R&D would be $14.53 billion. Thus the manufacturing sector would be worse off by $2.37 billion in terms of potential cost increase. In addition, the reduction of R&D tax incentives would increase the rental price of company-financed R&D which would reduce R&D investment by $15.98 billion. Onto that amount we have to add an additional $1.05 billion of reduction of company-financed R&D investment due to the crowding out effect of a 3.6% increase of publicly-financed R&D. Thus, keeping the government budget constant, an equiproportional change of R&D tax incentives and and publicly-financed R&D would reduce R&D investment in all industries of the manufacturing sector, and increase the after-tax cost of the whole sector (see table 9). However, the net effect on cost would not be the same for all industries. Publicly-financed R&D has a distributive effect: High-tech industries, for instance, machinery (35), electrical equipment (36), and transportation equipment (37), would be worse off, i.e., their after-tax costs would have increased. On the other hand, low-tech industries, for instance, food and kindred products (20) and other manufacturing industries (42), would be better off. The net effect would be to reduce the after-tax cost. This of course is not surprising since the low-tech industries have very small R&D cost shares, and thus the removal of the subsidies would affect their cost relatively less.

Conclusion

We have examined the effects of publicly-funded R&D and R&D tax policy on the cost structure and output of the manufacturing industries at the two-digit level. It has been shown that the effects of publicly-financed R&D are significant and vary across industries. Furthermore, we have shown that publicly-financed R&D and company-financed R&D are substitutes in low R&D intensive industries, while weak substitutes in high R&D intensive industries. Thus, an increase in publicly-financed R&D capital increases the efficiency, in terms of unit cost savings, of the industries of the manufacturing sector, but crowds out privately-financed R&D investment. On the other hand, it has been shown that the incremental R&D tax credit was modestly successful in inducing company-financed R&D, but also that if the government had to switch to a regime where R&D expenditures were treated like tangible investment, there would be a substantial reduction of privately-financed R&D investment. In conclusion, it seems that publicly-financed R&D investment is a more appropriate tool for increasing efficiency and possibly for stimulating output growth, while the R&D tax policy is a more appropriate tool for stimulating private sector's R&D investment. The optimal mix of both instruments, subsidies and direct financing of publicly financed R&D expenditures, is an important element for sustaining a balanced output growth and productivity in manufacturing sector.

Appendix A

OUTPUT (**Y**), LABOR (**L**), PHYSICAL CAPITAL (**K**), AND INTERMEDIATE INPUTS (**M**):

Data on the quantities and price indices of output, labor, physical capital and intermediate inputs were obtained from the Bureau of Labor Statistics (BLS) for the manufacturing industries at the two-digit level, reported in table 1. The sample covers the period from 1956 to 1988. All price indices have been normalized to be equal to one at 1982 value.

For each industry, the quantity of output is measured as the value of gross output divided by the output price index. The value of gross output corresponds to shipments plus the change of inventories, and is inclusive of any portion which is consumed by the same industry. The output price deflator index is implicitly defined by a Tornqvist aggregation of four-digit gross outputs.

The labor input quantity is measured as the cost of labor divided by the price of labor index. The labor input is measured in terms of man hours, estimated by the BLS Current Establishment Survey. It corresponds to the sum of hours of all persons engaged in production in the industry. The price deflator of labor is measured implicitly by dividing the labor compensation by the labor hours.

The price of intermediate inputs is derived by a Tornqvist index of the price indices of materials, energy, and purchased services, obtained from BLS. The quantity of intermediate inputs is measured as the total cost of materials, energy, and purchased services divided by the price index of intermediate inputs. All price deflators of the above inputs have been constructed implicitly by using a Tornqvist index to aggregate the corresponding quantities.[12]

Since own R&D is explicitly introduced as an input of production, the quantities of labor and intermediate inputs are adjusted for their R&D components in order to avoid double counting (see Schankerman (1981)). For labor, the R&D labor cost, i.e., the wages of scientists, engineers, and supporting personnel, has been subtracted from the total labor cost; for intermediate inputs, the materials and supplies component of R&D has been subtracted from the total intermediate input cost. The overhead cost component of R&D weighted by the cost share of labor and intermediate inputs has been subtracted from both labor and intermediate inputs. The R&D cost components have been obtained from Research and Development in Industry (various issues). Finally, the prices of output, labor and intermediate inputs are multiplied by one minus the corporate income tax to convert them to after-tax prices. For the period before 1981, the corporate income tax rate has been obtained from Auerbach (1983) and Jorgenson and Sullivan (1981); for the period 1981 to 1985, the rate remains the same at .46, while it was reduced to .34 in 1986 by the Tax Reform Act (TRA).

The physical capital stock is defined as the sum of structures and equipment capital stock which have been constructed by the perpetual inventory method. The deflator of physical capital is derived as a Tornqvist index of the investment price deflators of structures and equipment.

The rental rate of physical capital is measured as $p_K = q_K (r+\delta_K)(1 - \iota_K - u_c \sigma)$ (see Bernstein and Nadiri (1987)), where q_K is the physical capital deflator, r is the discount rate taken to be the rate on Treasury notes of ten-year maturity obtained from Citibase, δ_K is the physical capital depreciation rate obtained from BLS, ι_K is the investment tax credit, u_c is the corporate income tax rate, and σ is the present value of capital consumption allowances. The investment tax credit until 1980 is taken from Jorgenson and Sullivan (1981); 8% is used for 1981, and 7.5% for 1982 to 1985; finally, the rate is zero for 1986 when it was abolished by the TRA. The present values of capital consumption allowances are constructed as $\sigma = \rho\,(1 - \theta\, \iota_K)/(r + \rho)$ (see Bernstein and Nadiri (1987)), where ρ is the capital consumption allowance rate obtained by dividing the capital consumption allowances by the capital stock, and θ takes value 0 except for the 1962-1963 period in which firms had to reduce the depreciable base of the assets by half of the amount of the investment tax credit under the Long Amendment Act.

COMPANY-FINANCED R&D (**R**) AND PUBLICLY FINANCED R&D (**G**):

Privately-financed R&D capital is constructed using the perpetual inventory method with a 10% depreciation rate. A constant depreciation rate of 10% has been used in many studies of R&D spillovers (see, for instance, Bernstein and Nadiri (1990) and U.S. Department of Labor (1989)). The deflated company-financed R&D expenditures are accumulated for the period 1956-1988. The initial privately-financed R&D capital stock is found by dividing the real R&D expenditures of the year 1957 by the sum of the R&D depreciation rate and the average growth rate of physical capital for the period 1948-1956. The company-financed R&D expenditures have been obtained from Research and Development in Industry (various issues). The price deflator of R&D capital is constructed by linking Mansfield's (1985) constructed deflator series backward with Schankerman's (1979) constructed R&D deflator series, and forward with the GNP deflator. Mansfield's R&D deflator series goes from 1969 to 1983. Schankerman's goes from 1957 to 1975. For the years prior to 1957 and after 1983, the Schankerman and Mansfield deflators are linked to the GNP deflator. The after-tax rental rate of R&D capital is defined by the equation (5) in the text (see discussion there and table 4).

Government R&D capital stock is constructed along the same lines as company-financed R&D capital stock, i.e., by using the perpetual inventory method with a 10% depreciation rate. Data on total federal government financed R&D expenditures for the period 1970-1988 were obtained from the Federal Funds for Research and Development (1992). For the period 1953-1970, they were obtained from Historical Statistics, Colonial Times to 1970 (1975). These series consist of the total publicly-financed R&D expenditures performed by the industries, government agents, and nonprofit institutions. The implicit price deflator of government purchases of goods and services, obtained from the Statistical Abstracts of the United States (1990), was used to deflate the R&D expenditure series. The 1952 benchmark is estimated by dividing the R&D expenditures by the sum of government R&D depreciation rate and the growth rate of the government physical capital stock (obtained from the Bureau of Economic Analysis) prior to the sample period.

Notes

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[1] See, for instance, Arrow (1969), Atkinson and Stiglitz (1980), and Varian (1984).

[2] Evidence of the effectiveness of R&D tax incentives in encouraging privately-financed R&D spending is somewhat mixed. Evidence from tax returns (Cordes (1989, 1988)), from surveys (Mansfield (1984, 1986)), from comparisons of the user cost (Cordes (1984), Cordes et al. (1987), Fullerton and Lyon (1983), and Hulten and Robertson (1984)), and from econometric estimates (Baily et al. (1985), Baily and Lawrence (1992), Hines (1991), and Hall (1992)) are not unambiguous. See Cordes (1988, 1989) for a review.

[3] Studies conducted at the industry or firm level, which usually estimate total factor productivity regressions (see Leonard (1971), Terleckyj (1974, 1984), Griliches (1980, 1986), Griliches and Lichtenberg (1984) and Lichtenberg and Siegel (1989)), have not found any evidence of a significant productivity effect from government funded R&D. Bartelsman (1990) has provided a mixture of evidence, while Nadiri and Mamuneas (1991) and Mamuneas (1993)), in a cost function framework, have found significant effects of total publicly-funded R&D. For a collection of case studies dealing with the effects of federal government's R&D policy see Nelson (1982).

[4] This was a necessary restriction, since preliminary estimation of a more general cost function caused the returns to scale to be unreasonably high and unstable. Also by not restricting the internal returns to scale, the technological change parameters consistently had the wrong sign, making it difficult to distinguish shifts of the cost function due to scale or technological change over time. Also note that we initially experimented with a more flexible functional form of cost function. These attempts were also not fruitful since the second order conditions were always violated.

[5] The credit has from then renewed at a rate of 20%. See Hall (1992) for a brief history of the credit rate, qualified expenditure rules and base levels during the period 1981-91.

[6] The parameter λ can be considered as the rate with which R&D expenditures are allowed to be deducted in the current period. To see the significance of immediate expensing of R&D expenditures compare it with the case in which the government allows only the economic depreciation of R&D expenditures be deducted from current income. The present value of the depreciation deductions of \$1 of R&D with a depreciation and discount rate of 10% is equal to .50 (= .10/(.10+.10)) and the parameter λ takes the value .50.

[7] For 1981 $\nu = (1-.5/(1+r)-\sum_{i=2}^{3} .33/(1+r)^{i})$ since for 1982 the base was the average of R&D expenditures of 1980 and 1981 (see Eisner et al. (1984)).

[8] However, the hypothesis that the mean elasticities are equal across industries has been tested and rejected.

[9] The elasticity of cost with respect of Tax incentives is given by

$$\eta^{h}_{CT} = \partial \ln C^{h} / \partial \ln T = S^{h}_{R} (\partial \ln p^{h}_{R} / \partial \ln T)$$

[10] Cordes (1989) has estimated that the credit stimulated about $560 million to $1.5 billion, while Hall (1992) has estimated that the additional spending stimulated is about $2 billion 1982 dollars per year.

[11] Kaizuka (1965) was the first to derive the conditions of production efficiency when collective goods are used as inputs in the production process. Sandmo (1972) explored the general equilibrium implications of these conditions.

[12] For a detailed description and construction of data obtained from BLS, see Gullickson and Harper (1986, 1987).

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Table 1: **SIC Classification**

Code	SIC Codes	Industry
20	20	Food and Kindred Products
26	26	Paper and Allied Products
28	28	Chemicals and Allied Products
29	29	Petroleum Refining and Related Industries
30	30	Rubber Products
32	32	Stone, Clay, and Glass Products
33	33	Primary Metals
34	34	Fabricated Metal Products
35	35	Machinery
36	36	Electrical Equipment
37	37	Transportation Equipment
38	38	Scientific Instruments
40	22, 23	Textiles and Apparel
41	24, 25	Lumber, Wood Products, and Furniture
42	21, 27, 31, 39	Other Manufacturing Industries

Table 2: **Estimation Results**

Parameter	Estimate	Std. Error
β_0	.535655	.133291
β_L	.222360	.017493
β_K	.045632	.023763
β_R	.042240	.989446E-02
β_t	.023655	.013362
β_{LK}	.039211	.336216E-02
β_{LR}	.268750E-02	.288281E-02
β_{Lt}	.412688E-03	.210605E-03
β_{KR}	.760188E-02	.270975E-02
β_{Kt}	-.440546E-02	.181472E-03
β_{Rt}	.112135E-02	.159591E-03
ϕ_s	-.054387	.024096
ϕ_{Ls}	-.682079E-02	.311705E-02
ϕ_{Ks}	.028133	.429906E-02
ϕ_{Rs}	-.884186E-02	.182185E-02
ϕ_{ts}	-.478593E-02	.223432E-02

Equation	Std. Error	R^2
Cost	.0567	.993
Labor Share	.0131	.974
Phys. Capital Share	.0209	.870
R&D Capital Share	.697E-02	.880

Log of Likelihood	5327	

Table 3: **Hypothesis Testing**

Specification	Log of Likel.	X^2/d.fr.	$X^2_{c,0.05}$/d.fr.
1. $\alpha_0=\alpha_L=\alpha_K=\alpha_R=\gamma_s=0$	2394	83.80	1.29
2. $\alpha_0=\alpha_L=\alpha_K=\alpha_R=0$	3384	69.39	1.33
3. $\gamma_s=0$	5251	10.84	1.69
4. $\gamma_s=\phi=0$	5166	16.94	1.59
5. $\beta_t=\beta_{Lt}=\beta_{Kt}=\beta_{Rt}=\phi_{st}=0$	5137	76.00	2.21
6. $\alpha_0=0$	5290	5.28	1.69
7. $\alpha_L=0$	4445	126.00	1.69
8. $\alpha_K=0$	4937	55.71	1.69
9. $\alpha_R=0$	5074	36.14	1.69

Table 4: **Unit Cost of Company Financed R&D Investment**

Period	After Tax Cost	Expensing	Effective R&D Tax Credit	Statutory R&D Tax Credit	Discount Rate
		$\lambda\ u_c$	$\nu\ \zeta$	ζ	r
1981	0.520	0.46	0.020	0.25	0.140
1982	0.487	0.46	0.053	0.25	0.130
1983	0.493	0.46	0.047	0.25	0.110
1984	0.489	0.46	0.051	0.25	0.120
1985	0.495	0.46	0.045	0.25	0.110
1986	0.633	0.34	0.027	0.20	0.077
1987	0.631	0.34	0.029	0.20	0.084
1988	0.629	0.34	0.031	0.20	0.089
Average	0.547	0.42	0.038	0.23	0.107

Table 5: **Conditional Input Demand Price Elasticities**
(Mean values, 1956-1988; Stand. Error in Parenthesis)

Code	Price / Demand	Labor	Physical Capital	R&D Capital	Interm. Inputs
20	Labor	-0.855 (0.009)	0.375 (0.022)	0.122 (0.024)	0.358 (0.045)
	Phys. Capital	0.548 (0.106)	-0.896 (0.025)	0.081 (0.022)	0.267 (0.105)
	R&D Capital	1.130 (0.342)	2.888 (0.977)	-0.997 (0.001)	-3.021 (1.319)
	Inter. Inputs	0.089 (0.008)	0.041 (0.022)	-0.011 (0.002)	-0.120 (0.025)
26	Labor	-0.778 (0.010)	0.396 (0.045)	0.231 (0.045)	0.151 (0.090)
	Phys. Capital	0.410 (0.048)	-0.781 (0.045)	0.043 (0.011)	0.328 (0.023)
	R&D Capital	0.739 (0.254)	1.683 (0.746)	-0.994 (0.003)	-1.428 (0.997)
	Inter. Inputs	0.145 (0.010)	0.134 (0.038)	-0.012 (0.004)	-0.267 (0.030)
28	Labor	-0.814 (0.015)	0.440 (0.045)	0.242 (0.055)	0.132 (0.109)
	Phys. Capital	0.371 (0.050)	-0.772 (0.056)	0.075 (0.019)	0.327 (0.029)
	R&D Capital	0.258 (0.029)	0.433 (0.097)	-0.961 (0.009)	0.270 (0.115)
	Inter. Inputs	0.108 (0.010)	0.141 (0.047)	0.020 (0.011)	-0.269 (0.040)
29	Labor	-0.934 (0.017)	0.802 (0.144)	0.206 (0.055)	-0.074 (0.104)
	Phys. Capital	0.363 (0.125)	-0.838 (0.066)	0.073 (0.027)	0.402 (0.088)
	R&D Capital	0.251 (0.046)	0.685 (0.132)	-0.985 (0.004)	0.049 (0.173)
	Inter. Inputs	0.010 (0.012)	0.099 (0.060)	0.002 (0.004)	-0.111 (0.069)

Table 5 (cont'd)

Code	Price / Demand	Labor	Physical Capital	R&D Capital	Interm. Inputs
30	Labor	-0.710	0.307	0.181	0.223
		(0.014)	(0.036)	(0.038)	(0.078)
	Phys. Capital	0.534	-0.829	0.061	0.233
		(0.074)	(0.038)	(0.016)	(0.056)
	R&D Capital	0.495	0.752	-0.986	-0.261
		(0.054)	(0.152)	(0.003)	(0.201)
	Inter. Inputs	0.209	0.082	-0.006	-0.285
		(0.011)	(0.031)	(0.004)	(0.028)
32	Labor	-0.710	0.370	0.245	0.095
		(0.009)	(0.053)	(0.051)	(0.101)
	Phys. Capital	0.467	-0.765	0.045	0.252
		(0.053)	(0.051)	(0.013)	(0.022)
	R&D Capital	0.557	0.989	-0.989	-0.557
		(0.072)	(0.251)	(0.004)	(0.319)
	Inter. Inputs	0.199	0.133	-0.011	-0.321
		(0.013)	(0.042)	(0.005)	(0.026)
33	Labor	-0.782	0.390	0.222	0.170
		(0.008)	(0.033)	(0.034)	(0.069)
	Phys. Capital	0.410	-0.790	0.044	0.336
		(0.033)	(0.034)	(0.008)	(0.011)
	R&D Capital	0.707	1.594	-0.994	-1.308
		(0.174)	(0.497)	(0.002)	(0.668)
	Inter. Inputs	0.144	0.127	-0.012	-0.258
		(0.008)	(0.029)	(0.003)	(0.025)
34	Labor	-0.683	0.246	0.131	0.306
		(0.011)	(0.017)	(0.017)	(0.036)
	Phys. Capital	0.645	-0.878	0.070	0.163
		(0.054)	(0.017)	(0.011)	(0.048)
	R&D Capital	0.786	1.450	-0.994	-1.243
		(0.135)	(0.364)	(0.002)	(0.498)
	Inter. Inputs	0.241	0.038	-0.012	-0.267
		(0.009)	(0.015)	(0.002)	(0.014)

Table 5 (cont'd)

Code	Price / Demand	Labor	Physical Capital	R&D Capital	Interm. Inputs
35	Labor	-0.667 (0.020)	0.251 (0.020)	0.141 (0.024)	0.274 (0.058)
	Phys. Capital	0.638 (0.046)	-0.867 (0.025)	0.091 (0.024)	0.138 (0.043)
	R&D Capital	0.436 (0.062)	0.422 (0.142)	-0.968 (0.014)	0.110 (0.190)
	Inter. Inputs	0.250 (0.016)	0.040 (0.019)	0.011 (0.015)	-0.300 (0.018)
36	Labor	-0.666 (0.021)	0.232 (0.015)	0.122 (0.014)	0.312 (0.032)
	Phys. Capital	0.683 (0.046)	-0.886 (0.014)	0.116 (0.016)	0.086 (0.037)
	R&D Capital	0.394 (0.037)	0.283 (0.050)	-0.951 (0.013)	0.274 (0.073)
	Inter. Inputs	0.251 (0.020)	0.021 (0.011)	0.028 (0.014)	-0.300 (0.012)
37	Labor	-0.752 (0.009)	0.279 (0.024)	0.131 (0.026)	0.343 (0.053)
	Phys. Capital	0.593 (0.091)	-0.880 (0.026)	0.102 (0.028)	0.185 (0.092)
	R&D Capital	0.339 (0.046)	0.380 (0.127)	-0.965 (0.014)	0.246 (0.159)
	Inter. Inputs	0.177 (0.008)	0.042 (0.023)	0.018 (0.014)	-0.237 (0.018)
38	Labor	-0.625 (0.030)	0.232 (0.019)	0.134 (0.023)	0.259 (0.062)
	Phys. Capital	0.696 (0.053)	-0.873 (0.023)	0.115 (0.037)	0.063 (0.060)
	R&D Capital	0.438 (0.058)	0.307 (0.098)	-0.947 (0.025)	0.202 (0.131)
	Inter. Inputs	0.280 (0.026)	0.021 (0.018)	0.030 (0.026)	-0.331 (0.013)

Table 5 (cont'd)

Code	Price / Demand	Labor	Physical Capital	R&D Capital	Interm. Inputs
40	Labor	-0.660	0.232	0.125	0.303
		(0.010)	(0.018)	(0.019)	(0.041)
	Phys. Capital	0.687	-0.883	0.071	0.125
		(0.070)	(0.019)	(0.015)	(0.067)
	R&D Capital	1.365	3.015	-0.997	-3.383
		(0.534)	(1.510)	(0.002)	(2.043)
	Inter. Inputs	0.263	0.030	-0.016	-0.277
		(0.008)	(0.016)	(0.002)	(0.015)
41	Labor	-0.719	0.249	0.119	0.351
		(0.007)	(0.023)	(0.022)	(0.044)
	Phys. Capital	0.658	-0.891	0.075	0.158
		(0.100)	(0.022)	(0.020)	(0.099)
	R&D Capital	2.613	6.705	-0.998	-8.319
		(1.486)	(4.228)	(0.001)	(5.713)
	Inter. Inputs	0.212	0.032	-0.015	-0.229
		(0.008)	(0.020)	(0.001)	(0.016)
42	Labor	-0.701	0.267	0.144	0.291
		(0.016)	(0.030)	(0.033)	(0.071)
	Phys. Capital	0.614	-0.865	0.063	0.188
		(0.104)	(0.033)	(0.022)	(0.095)
	R&D Capital	2.170	5.429	-0.998	-6.601
		(0.902)	(2.540)	(0.001)	(3.441)
	Inter. Inputs	0.224	0.052	-0.016	-0.259
		(0.012)	(0.027)	(0.002)	(0.029)

Table 6: **Elasticities of Incremental R&D Tax Credit**
(Mean Values 1981-1988)

Code	Cost	R&D Capital	Labor	Physical Capital	Interm. Inputs
20	-0.0003	0.0717	-0.0070	-0.0075	0.0006
26	-0.0007	0.0713	-0.0130	-0.0041	0.0005
28	-0.0037	0.0683	-0.0128	-0.0072	-0.0025
29	-0.0012	0.0709	-0.0103	-0.0078	-0.0003
30	-0.0013	0.0708	-0.0097	-0.0059	0.0000
32	-0.0012	0.0709	-0.0137	-0.0043	0.0003
33	-0.0007	0.0713	-0.0151	-0.0036	0.0006
34	-0.0006	0.0714	-0.0088	-0.0056	0.0007
35	-0.0038	0.0682	-0.0090	-0.0086	-0.0024
36	-0.0047	0.0673	-0.0084	-0.0098	-0.0033
37	-0.0040	0.0681	-0.0078	-0.0099	-0.0027
38	-0.0065	0.0655	-0.0078	-0.0121	-0.0049
40	-0.0004	0.0717	-0.0075	-0.0063	0.0009
41	-0.0002	0.0719	-0.0069	-0.0068	0.0010
42	-0.0002	0.0718	-0.0078	-0.0061	0.0010

Table 7: **Elasticities of R&D Expensing**
(Mean values 1981-1988)

Code	Cost	R&D Capital	Labor	Physical Capital	Interm. Inputs
20	-0.0037	0.7775	-0.0760	-0.0814	0.0067
26	-0.0080	0.7732	-0.1410	-0.0443	0.0053
28	-0.0404	0.7407	-0.1382	-0.0785	-0.0274
29	-0.0127	0.7684	-0.1113	-0.0849	-0.0033
30	-0.0140	0.7671	-0.1060	-0.0637	0.0000
32	-0.0127	0.7684	-0.1482	-0.0471	0.0029
33	-0.0076	0.7735	-0.1609	-0.0391	0.0062
34	-0.0068	0.7743	-0.0952	-0.0613	0.0072
35	-0.0415	0.7396	-0.0973	-0.0936	-0.0262
36	-0.0515	0.7297	-0.0916	-0.1070	-0.0359
37	-0.0430	0.7381	-0.0844	-0.1080	-0.0298
38	-0.0707	0.7104	-0.0845	-0.1308	-0.0535
40	-0.0043	0.7768	-0.0816	-0.0678	0.0099
41	-0.0020	0.7791	-0.0751	-0.0740	0.0107
42	-0.0026	0.7785	-0.0854	-0.0664	0.0106

Table 8: **Elasticities of Publicly Funded R&D**
(Mean values 1956-1988; Stand. Error in parenthesis)

Code	Cost	Labor	Physical Capital	R&D Capital	Interm. Inputs	Marginal Benefit
20	-0.147	-0.194	0.124	-3.020	-0.164	0.043
	(0.043)	(0.049)	(0.058)	(0.589)	(0.044)	(0.013)
26	-0.132	-0.163	-0.004	-1.506	-0.155	0.012
	(0.043)	(0.046)	(0.047)	(0.282)	(0.044)	(0.004)
28	-0.123	-0.160	0.001	-0.350	-0.146	0.022
	(0.043)	(0.047)	(0.046)	(0.061)	(0.044)	(0.008)
29	-0.024	-0.127	0.150	-0.598	-0.040	0.004
	(0.043)	(0.067)	(0.051)	(0.122)	(0.043)	(0.006)
30	-0.201	-0.225	-0.037	-0.845	-0.225	0.012
	(0.043)	(0.045)	(0.049)	(0.136)	(0.044)	(0.003)
32	-0.057	-0.081	0.063	-0.861	-0.084	0.003
	(0.043)	(0.045)	(0.046)	(0.167)	(0.045)	(0.002)
33	0.068	0.036	0.202	-1.355	0.046	-0.011
	(0.043)	(0.046)	(0.047)	(0.293)	(0.044)	(0.007)
34	-0.085	-0.106	0.145	-1.521	-0.107	0.011
	(0.043)	(0.045)	(0.054)	(0.295)	(0.044)	(0.006)
35	-0.241	-0.262	-0.030	-0.519	-0.266	0.050
	(0.043)	(0.045)	(0.053)	(0.069)	(0.044)	(0.009)
36	-0.314	-0.334	-0.067	-0.495	-0.338	0.053
	(0.043)	(0.045)	(0.056)	(0.055)	(0.045)	(0.007)
37	-0.088	-0.116	0.146	-0.341	-0.109	0.024
	(0.043)	(0.046)	(0.055)	(0.064)	(0.044)	(0.012)
38	-0.136	-0.154	0.086	-0.304	-0.164	0.007
	(0.043)	(0.045)	(0.054)	(0.053)	(0.045)	(0.002)
40	-0.100	-0.120	0.141	-2.723	-0.123	0.013
	(0.043)	(0.045)	(0.055)	(0.538)	(0.044)	(0.006)
41	-0.246	-0.271	0.011	-5.841	-0.267	0.030
	(0.043)	(0.045)	(0.057)	(1.150)	(0.044)	(0.005)
42	-0.207	-0.230	0.002	-4.934	-0.229	0.018
	(0.043)	(0.045)	(0.053)	(0.970)	(0.044)	(0.004)
Sum of Marginal Benefits						0.290
						(0.081)

Table 9: The Effect of Reduction of R&D Tax Incentives and Increase of Public R&D on Different Industries
(In billions of 1988 dollars)

Code	Reduction of R&D Tax Incentives: Cost (Revenue)			Reduction of R&D Tax Incentives: R&D Capital			Increase of Publicly Financed R&D		Net Effect	
	Total	Credit	Expen-sing	Total	Credit	Expen-sing	Cost	R&D Capital	Cost	R&D Capital
20	0.31	0.05	0.26	-0.30	-0.05	-0.26	-1.83	-0.08	-1.53	-0.38
26	0.22	0.03	0.19	-0.22	-0.03	-0.19	-0.62	-0.03	-0.40	-0.25
28	2.74	0.42	2.32	-2.59	-0.40	-2.19	-1.24	-0.12	1.50	-2.71
29	0.71	0.11	0.60	-0.69	-0.11	-0.58	-0.40	-0.04	0.31	-0.73
30	0.26	0.04	0.22	-0.25	-0.04	-0.21	-0.61	-0.03	-0.35	-0.28
32	0.25	0.04	0.21	-0.24	-0.04	-0.21	-0.23	-0.02	0.02	-0.26
33	0.29	0.05	0.25	-0.29	-0.04	-0.25	-0.11	-0.03	0.18	-0.33
34	0.26	0.04	0.22	-0.26	-0.04	-0.22	-0.66	-0.04	-0.40	-0.30
35	3.06	0.47	2.59	-2.88	-0.44	-2.44	-1.97	-0.17	1.10	-3.05
36	3.10	0.47	2.62	-2.89	-0.44	-2.45	-2.21	-0.19	0.89	-3.09
37	4.00	0.61	3.38	-3.78	-0.58	-3.20	-1.61	-0.16	2.38	-3.95
38	1.37	0.21	1.16	-1.23	-0.19	-1.05	-0.38	-0.05	0.99	-1.29
40	0.21	0.03	0.18	-0.21	-0.03	-0.18	-0.85	-0.04	-0.64	-0.25
41	0.07	0.01	0.06	-0.07	-0.01	-0.06	-1.01	-0.03	-0.94	-0.10
42	0.06	0.01	0.05	-0.06	-0.01	-0.05	-0.80	-0.03	-0.74	-0.09
TOTAL	16.90	2.59	14.31	-15.98	-2.45	-13.53	-14.53	-1.05	2.37	-17.03